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EMERGENCY CONSERVATION WORK
FORESTRY PUBLICATION No. 1

MEASURES FOR STAND IMPROVEMENT IN SOUTHERN APPALACHIAN FORESTS

PREPARED BY THE
STAFF OF THE APPALACHIAN FOREST EXPERIMENT STATION
UNITED STATES FOREST SERVICE

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Prepared by the
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United States Forest Service

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CONTENTS

MEASURES FOR STAND IMPROVEMENT IN SOUTHERN APPALACHIAN FORESTS

By the Staff of the Appalachian Forest Experiment Station, Forest Service[1]

INTRODUCTION

This publication is intended to assist foresters who, with perhaps no previous experience in stand-improvement work, are called upon to perform such work in the forests of the southern Appalachian region. This region presents a striking example of multiplicity of forest conditions, brought about by many factors operating over long periods of time on stands in which a great number of tree species are variously associated. It is not practical to recommend improvement measures for the forests of the region, therefore, except as alternative measures among which the man on the ground will make a selection for each individual stand. In order to choose the proper treatment for improving each stand the forester must be able to recognize, among other things, its component species, its condition, and the productive capacity of the site. Dealing briefly with a great complexity of conditions, the publication indicates what kind of silvicultural work should be done, how it should be done, and where it should be done. Many of the descriptions and recommendations included apply more or less generally to forest conditions elsewhere in the Eastern States.

The southern Appalachian region, a map of which appears as figure 1, consists of two long, rugged mountain systems: in the west, the Alleghenies and the Cumberlands; and on the east, the Blue Ridge and Smoky Ranges and cross ranges. The mountains are mostly forest land.

STAND IMPROVEMENT

The purpose of stand-improvement work is to bring rundown or inadequately productive forest stands into better condition for timber production and watershed and soil protection. In most cases these two aims are entirely compatible.

The conditions to be dealt with fall generally into five classes: (1) The presence of defective, unmerchantable old-growth trees that impede or prevent the development of a young and vigorous stand; (2) over-density of second-growth stands, and particularly the presence in such stands of defective trees and poor species that reduce both the quality and the potential growth rate of the stands; (3) the presence, in young reproduction that has followed cutting or fire, of large numbers of worthless shrubs, vines, and tree sprouts

[1] The publication was prepared under the immediate direction of C. R. Hursh.

and of seedlings that are defective or of poor species; (4) the absence of desirable reproduction, usually the result of repeated burning; and (5) the absence of tree growth on abandoned farm lands subject to erosion.

To correct these conditions involves (1) improvement and liberation cuttings in the old growth; (2) improvement cuttings and thinnings in the second growth; (3) cleanings in the reproduction; (4) establishment of new reproduction either by insuring a natural seed supply and good seed-bed conditions or by underplanting the stand; and (5) planting forest trees on cleared land, to retard water run-

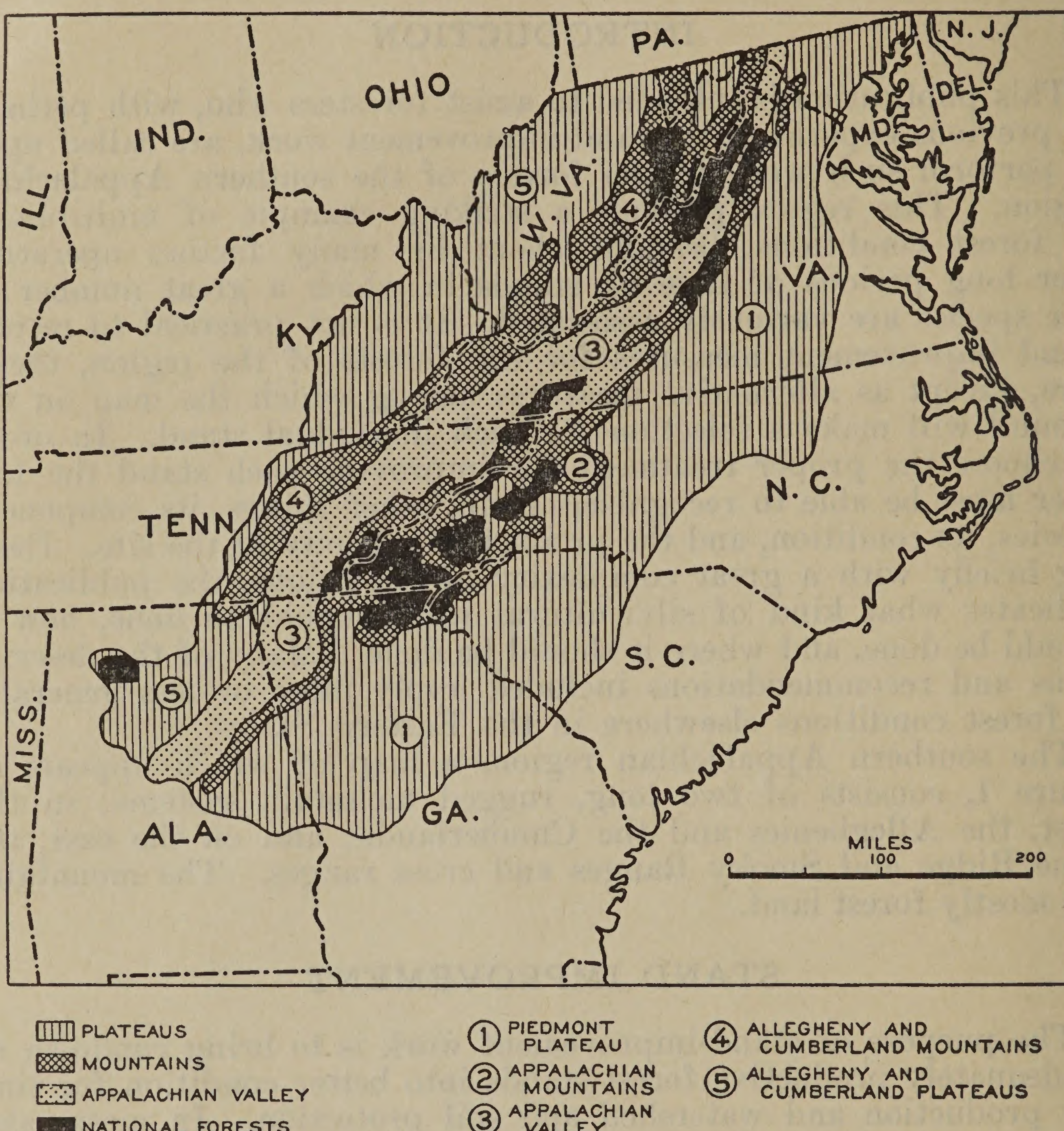

FIGURE 1.—Southern Appalachian region.

off and erosion and to provide a future source of wood products. Improvement of conditions on forest areas as to watershed protection and erosion control involves certain other measures calculated to increase the water-absorptive capacity of the soil. The nature of these corrective measures will be defined later.

In the case of the first three measures listed a single treatment gives lasting benefit, though the effectiveness of thinnings and cleanings can be increased by later treatments at intervals of 5 or 10 years. Initial measures to establish new reproduction cannot be expected to succeed fully unless measures are applied later to save the young

reproduction from shading or adverse competition. In the case of planting on cleared land, also, follow-up work is usually required to prevent loss. (Planting methods are not discussed in this publication.)

The specific character of the improvement measures needed on a given area depends upon the composition of the forest, the site, and other factors, which will be discussed briefly before the measures themselves are described.

MAJOR FOREST TYPES

Forest-tree species native to the Appalachian region number about 120. About 55 of these, including about 45 species of hardwoods, are important commercially.[2] The combinations in which the species occur are extremely varied, especially in the mountains.

For convenience of discussion, the forests of the region will be grouped into six major types.[3] For each of these major forest types, except the spruce type, the species present will be listed, in the order of their relative silvicultural importance as determined by quality of wood products, vigor and growth rate, and general desirability.

SPRUCE

The spruce forest of the southern Appalachians occurs at elevations of 3,200 feet or more in West Virginia and of 4,500 feet or more in Virginia, Tennessee, and North Carolina. It occupies only a small total area. The largest areas forested with this type center on the Black Range and on the Great Smoky and Balsam Mountain Ranges. The most extensive remaining virgin stands of spruce occur in the Great Smoky Mountains National Park. Clear cutting has been practiced in harvesting forests of this type, and almost without exception the logged areas have been burned over.

The burned areas need to be planted, but except on fresh burns the presence of dense thickets of pin cherry, shrubs, briars, and weeds, or of the reproduction of yellow birch and other hardwood trees, makes this an expensive procedure. Native spruce and balsam are the best species to plant in this type. It is recommended that 2-1 planting stock be used, spaced 8 by 8 feet. For the poorer sites 2-2 stock is recommended.

Where uncut stands of spruce and balsam border burned and cut areas, these species may seed in naturally. Any unmerchantable old hardwoods or unpromising young hardwoods overtopping such reproduction should be removed. The areas on which this treatment is needed are probably very small.

NORTHERN HARDWOODS

Northern hardwoods in the Appalachian region occupy the higher coves, and slopes and ridges at elevations of from 3,000 to more than 5,000 feet. On the better sites the type produces excellent timber; but on the higher ridges, where the soil is thin and climatic factors

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[2] A list of the principal forest-tree species of the region, including scientific as well as common names, appears as appendix B.

[3] The relationship of these six major types to the forest types recognized by a committee of the Society of American Foresters is shown in appendix A.

adverse, it produces only short-boled trees. Much of the area occupied by the northern hardwood type is relatively inaccessible, and in consequence the heaviest cutting and culling in this type have usually taken place at the lower altitudes and on the better sites. In the culled stands the present dominant old-growth canopy is made up of the most defective of the timber trees that were present in the original stand together with such species as were not sought at the time of cutting. Often an understory of reproduction was already present when the logging was done, of such shade-tolerant species as hemlock and sugar maple. Dense growths occur of less desirable species such as beech, mountain maple, and hophornbeam.

Forest species found within the type are named in the accompanying list, in general order of desirability.

SPECIES PRESENT IN THE NORTHERN HARDWOOD TYPE,[4] IN ORDER OF RELATIVE SILVICULTURAL DESIRABILITY

Better sites

Desirable:
- Red oak
- Basswood
- Sugar maple
- Black cherry
- White ash
- Yellow poplar
- Cucumber magnolia
- Yellow birch

Less desirable:
- Northern white pine
- Black birch
- White oak
- Black locust
- Hickory
- Red maple
- Elm
- Eastern hemlock
- Butternut

Least desirable:
- Buckeye
- Beech
- Chestnut
- Mountain magnolia
- Mountain maple
- Striped maple
- Pin cherry
- Rhododendron

Poorer sites

Desirable:
- Red oak
- Northern white pine
- Yellow birch
- Black locust

Less desirable:
- Chestnut oak
- Red maple
- Eastern hemlock

Least desirable:
- Buckeye
- Beech
- Chestnut
- Mountain maple
- Striped maple
- Pin cherry
- Mountain-laurel
- Rhododendron

OAK-CHESTNUT

The oak-chestnut type has an extremely wide altitudinal range in the southern Appalachian region, from 1,000 feet to 4,000 feet. It occurs on all sites within this range but particularly on the drier sites, which it shares with the yellow pine [5]-hardwood type. If yellow pine seed trees are present in or near a stand of oak-chestnut, pine reproduction may become established through silvicultural measures, or may enter the stand naturally after fire, wind throw, or blight killing of chestnut. The better sites on which the oak-

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[4] Key species: Sugar maple, yellow birch, beech.

[5] "Yellow pine" is used in this publication to indicate shortleaf, Virginia, pitch, and mountain pines.

chestnut type occurs are shared with various cove hardwoods; on the best sites it is not uncommon to find cove hardwoods entering the stand following ravages of chestnut blight. The oak-chestnut type shares some better sites with the white pine-hardwood type, also, and its composition may be materially influenced by this latter type.

Below 2,000 feet, particularly on the Cumberland plateau, the relative quantity of chestnut in the stands is considerably less.

Stands rendered unproductive by repeated culling are common within the oak-chestnut type. Frequently the old-growth overstory is made up almost entirely of defective trees, and the associated understory is sometimes composed of weed species. This condition represents one of the most difficult of silvicultural problems. For the most part, growing-stock conditions are now better in stands that were heavily cut than in stands that were repeatedly culled.

Forest species found within the oak-chestnut type are named in the accompanying list, in general order of desirability.

SPECIES PRESENT IN THE OAK-CHESTNUT TYPE,[6] IN ORDER OF RELATIVE SILVICULTURAL DESIRABILITY

Better sites

Desirable:
- Red oak
- White oak
- Yellow poplar
- Black locust
- Black oak
- Southern red oak

Less desirable:
- Scarlet oak
- Red maple
- Hickory
- Persimmon

Least desirable:
- Black gum
- Beech
- Chestnut
- Dogwood
- Silverbell
- Sassafras
- Witch-hazel
- Chinquapin
- Rhododendron
- Mountain-laurel

Poorer sites

Desirable:
- Black oak
- Chestnut oak
- Southern red oak

Less desirable:
- Black locust
- Scarlet oak
- Post oak
- Hickory

Least desirable:
- Black gum
- Red maple
- Chestnut
- Dogwood
- Blackjack oak
- Sourwood
- Sassafras
- Persimmon
- Witch-hazel
- Chinquapin
- Mountain-laurel

COVE HARDWOODS

The cove hardwood forest is found mostly in narrow coves and on moist slopes at elevations of from 500 to 5,000 feet, but at its best between 2,000 and 4,000 feet. This type represents the best opportunity for profitable forest management in the mountains, since it contains a large number of valuable, rapidly growing species and since the stands recover rapidly from cutting and fire.

The cove hardwoods have been more heavily logged than most of the other types, and the remaining old-growth timber is mostly difficult of access. Some of the less accessible stands have become over-

[6] Key species: Scarlet oak, chestnut oak, black oak, chestnut.

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mature and are actually retrograding on productive sites, preventing the land from becoming available for a vigorous growing stock. Moisture and soil conditions are usually favorable, but owing to the dense shade no reproduction except of the most shade-tolerant species is present. A dense growth of mountain-laurel and rhododendron sometimes makes up the understory for the cove hardwood type; but this is not usually the case on the best sites in the mountains, where the soil is generally less acid than on surrounding areas.

Forest species found within the cove hardwood type are named in the accompanying list in general order of desirability.

SPECIES PRESENT IN THE COVE HARDWOOD TYPE,[7] IN ORDER OF RELATIVE SILVICULTURAL DESIRABILITY

Better sites	*Poorer sites*
Desirable:	Desirable:
Yellow poplar	Yellow poplar
Red oak	White oak
Black cherry	Red oak
Black walnut	Northern white pine
White ash	Black oak
Cucumber magnolia	Black cherry
Basswood	Black locust
White oak	
Less desirable:	Less desirable:
Black oak	Black walnut
Black locust	Eastern hemlock
Hickory	Scarlet oak
Eastern hemlock	Hickory
Sweet birch	Sweet birch
Red maple	Red maple
Least desirable:	Least desirable:
Buckeye	Black gum
Black gum	Buckeye
Beech	Chestnut
Chestnut	Dogwood
Dogwood	Sourwood
Scarlet oak	Sassafras
Silverbell	Rhododendron
Sassafras	Mountain-laurel
Rhododendron	
Mountain-laurel	

YELLOW PINE-HARDWOOD

The name "yellow pine-hardwood type" is applied to stands characterized by yellow pines mixed with upland hardwoods, largely oaks. The yellow pine-hardwood type is found on moderately dry to very dry soils, extending from the piedmont and other plateaus, at altitudes of 500 feet or less, to elevations of 3,500 feet in the mountains. It reaches its best development on well-drained slopes and plateaus usually below the elevation of 2,500 feet. In the mountains it usually occupies the drier south or west exposures. At the lower elevations it commonly occupies better sites, and shortleaf pine is the most abundant and desirable of the yellow pines. Virginia pine is frequent at the lower altitudes. At the southern extremity of the Appalachian region, loblolly pine occasionally enters the type. Virginia pine and shortleaf pine are replaced by pitch and mountain pine at the higher elevations in the mountains. The pines and the many hardwood species associated with them in

[7] Key species: Yellow poplar, eastern hemlock, cucumber magnolia, basswood.

this type are named in the accompanying list in general order of desirability. The yellow pine-hardwood type is rarely found on sites I and II except in old fields.

The type may be said to share the drier sites with the oak-chestnut type. It may be considered simply as a dry-site form of the oak-chestnut type with the addition of yellow pine. Huckleberry and grasses often form a ground cover that interferes with the establishment of desirable tree reproduction.

On most of the sites on which the type is commonly found light to moderate cuttings have usually removed the pine, owing to the fact that the species has made much better growth and produced more desirable timber than have the hardwoods. The effect of these cuttings combined with the presence of undesirable advance growth has brought about an outstanding need of silvicultural improvement. In some cases advance growth of pine and desirable hardwoods is seriously overtopped by old-growth hardwoods of inferior quality. Also, on many areas the future development of this young pine reproduction is jeopardized by competing growth of undesirable hardwoods and shrubs. Situations are common in which satisfactory yellow pine seed trees are available. In such situations the logical procedure, in the absence of desirable hardwoods, is to make every effort to increase the proportion of pine. The major difficulties in the way are most frequently dense herbaceous cover and unfavorable light conditions.

SPECIES PRESENT IN THE YELLOW PINE-HARDWOOD TYPE,[8] IN ORDER OF RELATIVE SILVICULTURAL DESIRABILITY

Better sites

Desirable:
- Shortleaf pine
- Northern white pine [9]
- Black oak
- White oak
- Chestnut oak [9]
- Southern red oak
- Pitch pine [9]
- Virginia pine

Less desirable:
- Black locust
- Hickory
- Scarlet oak
- Mountain pine [9]
- Red gum
- Dogwood
- Persimmon

Least desirable:
- Black gum
- Red maple
- Post oak
- Chestnut
- Sourwood
- Blackjack oak
- Sassafras
- Silverbell [9]
- Mountain-laurel [9]

Poorer sites

Desirable:
- Shortleaf pine
- Pitch pine [9]
- Mountain pine [9]
- Chestnut oak [9]
- Virginia pine
- Black oak
- Southern red oak

Less desirable:
- Chestnut oak [9]
- Scarlet oak
- Post oak
- Hickory

Least desirable:
- Black gum
- Red maple
- Blackjack oak
- Dogwood
- Chestnut
- Sourwood
- Sassafras
- Silverbell [9]
- Chinquapin
- Turkey oak
- Mountain-laurel [9]

[8] Key species: Shortleaf, pitch, Virginia, and mountain pines.
[9] Species particularly abundant at higher altitudes in the yellow pine-hardwood type.

WHITE PINE-HARDWOOD

The white pine-hardwood type in the southern Appalachian region is found between altitudinal limits of 1,500 and 5,000 feet. Within the altitudinal ranges of the oak-chestnut and the yellow pine-hardwood types this type is often associated with the former on good sites and with the latter on the drier sites. Northern white pine rarely occupies an important place in the old-growth overstory. With better fire protection during the past decade it has, however, become important in the understory over a considerable area. The shade tolerance of white pine is such that the species is able to survive and make good growth in its younger stages while still overtopped. However, mechanical interference of the hardwood branches invariably injures the pine leaders, resulting in poor form. The growth rate and general desirability of the species justify giving every opportunity to white pine in the understory on good sites. It appears to be good silviculture to treat stands containing white pine with the idea of increasing the proportion of the species wherever possible.

Forest species found within the white pine-hardwood type are named in the accompanying list, in general order of desirability.

SPECIES PRESENT IN THE WHITE PINE-HARDWOOD TYPE,[10] IN ORDER OF RELATIVE SILVICULTURAL DESIRABILITY

Better sites

Desirable:
- Northern white pine
- Yellow poplar
- Red oak
- Black oak
- White oak

Less desirable:
- Eastern hemlock
- Hickory
- Red maple
- Birches

Least desirable:
- Black gum
- Chestnut
- Beech
- Dogwood
- Scarlet oak
- Sourwood
- Silverbell
- Rhododendron
- Mountain-laurel

Poorer sites

Desirable:
- Northern white pine
- Black oak
- White oak
- Red oak
- Chestnut oak
- Southern red oak

Less desirable:
- Scarlet oak
- Hickory

Least desirable:
- Black gum
- Red maple
- Chestnut
- Sourwood
- Dogwood
- Mountain-laurel
- Rhododendron

FOREST SITES

"Forest site" sums up the environmental factors that affect the composition of the forest and its rate of growth. These are chiefly climatic and soil factors. Atmospheric and soil moisture are probably the most important. Most trees grow better, other conditions being equal, on deep moist soils and in cool moist air than on shallow soils in dry sunny situations exposed to drying winds.

The most productive sites in the Appalachian region are found in the coves and stream bottoms, and on moist benches and northerly

[10] Key species: Northern white pine.

slopes. Here the soil is usually a deep, friable, dark-brown loam. In contrast with the coves, which represent the best of the productive sites, the upper slopes and ridges usually represent the poorest sites. Here the soil is shallow and lacks fertility. Occasional rock outcrops and cliffs occur, and the soil frequently contains a considerable quantity of rock fragments. North and east slopes are usually moist and contain a greater proportion of highly productive area than south or west slopes.

On moist sites the timber stands are usually dense, with a completely closed dominant canopy, and composed principally of tall mature trees containing 3 to 5 logs each. On dry sites the timber, particularly that of hardwood species, is short-bodied, mature trees containing from one half to one and one half logs each, stands are open, and the number of species present in the dominant canopy is frequently limited to four or five. Damage due to past fires is likely to be greater on the dry south and west slopes than on slopes with a north or east exposure.

Since forest tree species differ in their ability to withstand poor site conditions, the distribution of forest types depends largely upon site. Certain species including yellow poplar, eastern hemlock, and basswood grow only on relatively moist soils and hence are characteristic of the cove hardwood type. Chestnut oak, scarlet oak, black oak, and the yellow pines are examples of species able to endure much drier conditions.

Apparent exceptions to the moist- and dry-site relations just described are frequently met, as when forest unquestionably of the cove hardwood type is found on or near the tops of ridges, particularly in gaps. The explanation of such occurrences lies in the presence of pockets of relatively deep and fertile soil, resulting from the weathering of soft rock strata underlain by harder strata in the complex geologic folding that often prevails. The soil thus formed may have sufficient depth and a sufficiently continuous moisture supply to maintain cove hardwoods permanently. On the other hand its moisture supply, although sufficient to support a luxuriant vegetation during wet cycles of years, may be entirely insufficient to do so during drought years. Where this is the case the older forest vegetation includes only drought-resistant species such as chestnut oak and pitch pine, although much of the tree reproduction, in moist cycles of years, may be of cove species such as yellow poplar or hemlock. The key to the permanence of moist conditions on ridge tops therefore lies in the composition of the older forest, and the choice of species to be favored in stand-betterment measures should rest upon the character of the old growth, where such growth is present.

As has been indicated in the discussion of forest types, a rough correlation exists between elevation and the associations of species. For instance, the spruce-balsam forest is found only at the highest elevations, the northern hardwoods at somewhat lower altitudes, and other forest types still lower. In the southern Appalachians there is no sharply defined altitudinal banding of types, however.

Such types as the northern hardwood, cove hardwood, and white pine-hardwood are characteristic of north rather than south exposures, and the reverse is true of the yellow pine-hardwood type and the dry-site phases of the oak-chestnut type.

Where there is doubt as to which of the major types is present, the following generalized list of species characteristic of dry and of moist sites may be used as a guide in deciding upon the species to be favored in the cultural operation:

DRY-SITE [11] SPECIES

Desirable	Less Desirable	Least Desirable
Northern white pine	Hickory	Post oak
Chestnut oak	Black gum	Dogwood
Black locust	Red maple	Persimmon
Shortleaf pine	Scarlet oak	Blackjack oak
Black oak	Mountain pine	Sassafras
Eastern red cedar	Carolina hemlock	Serviceberry
Virginia pine		Sourwood
Southern red oak		Chestnut
Pitch pine		Chinquapin
		Silverbell
		Mountain-laurel

MOIST-SITE [12] SPECIES

Desirable	Less Desirable	Least Desirable
Yellow poplar	Eastern hemlock	Chestnut
Black walnut	Beech	Blue beech
Northern white pine	Buckeye	Pin cherry
White ash	Hickory	Crab apple
Red oak	Red maple	Hawthorns
White oak	Sweet birch	Hop-hornbeam
Black cherry	Butternut	Mountain magnolia
Sugar maple	Sycamore	Umbrella magnolia
Basswood	Black gum	Striped maple
Cucumber magnolia	Coffeetree	Red mulberry
Black locust	Elm	Mountain-ash
Yellow birch	Honey locust	Redbud
Red spruce	Red gum	Rhododendron
	Holly	Silverbell
	River birch	Witch-hazel
	Black willow	
	Southern balsam fir	

CLASSIFICATION OF SITE QUALITY

Site quality is ordinarily defined in terms of the height attained by dominant trees at a given age. On this basis the sites represented in the oak-chestnut, cove hardwood, white pine-hardwood, and yellow pine-hardwood forests of the southern Appalachian region have been classified by the Appalachian Forest Experiment Station in five groups, which are indicated by the height-age curves in figure 2.[13] For many stand-improvement operations precise identification of site quality is not necessary. Figure 2 will be useful chiefly in rough determination of sites, effected by estimating the heights of mature trees and comparing the estimated heights with the heights indicated by the right-hand extremities of the curves. This classification based upon the height of mature dominant trees is shown in table 1 in contrast with the classification used in national-forest acquisition in the East:

[11] The yellow pine-hardwood type is characteristic of dry sites. The oak-chestnut type occurs usually on dry sites, although it sometimes occurs on moist sites.

[12] The types characteristic of moist sites are spruce, northern hardwood, cove hardwood, and white pine-hardwood. (The last mentioned is occasionally found on dry sites.)

[13] Yields per acre for the 5 sites are shown in table 8 of Timber Growing and Logging Practice in the Southern Appalachian Region, U.S. Dept. of Agr. Tech Bul. 250.

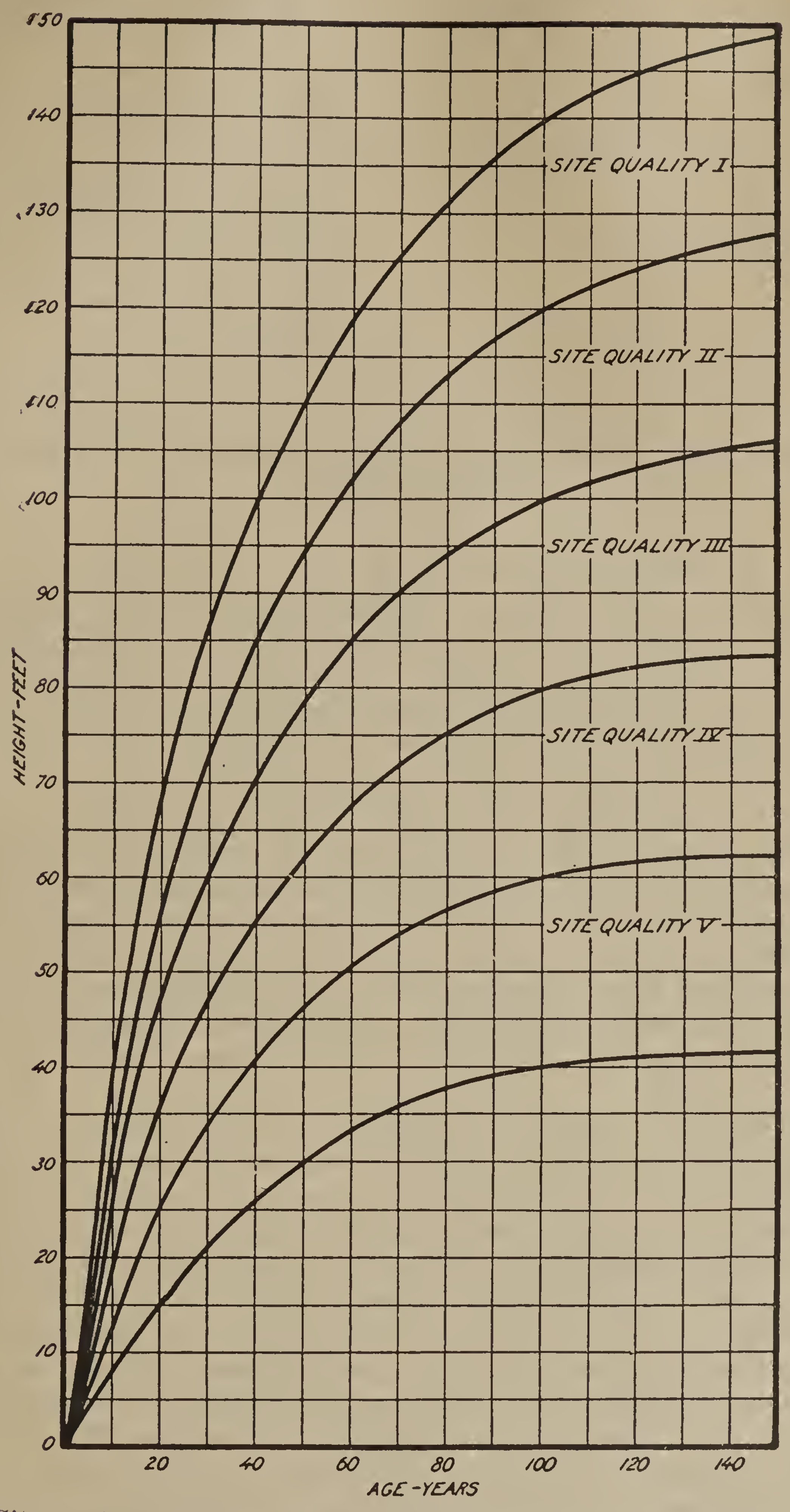


FIGURE 2.—Site quality classes in southern Appalachian hardwood forests, as indicated by heights of dominant trees at different ages. The classification is applicable in stands containing dominant yellow poplar, red oak, black oak, chestnut oak, scarlet oak, or chestnut. In using these curves to determine site quality only dominant trees should be used, preferably of the species just named.

TABLE 1.—*Classification of forest sites for the southern Appalachian region*

Site	Height of dominants at maturity	National-forest site classification, based upon average stand, in board feet, per acre
Best, I and II	105 feet or more	Cove grade no. 1 and no. 2: Hardwoods, 8 M and up. Yellow pine, 12 M and up. White pine and hemlock, 16 M and up.
Average, III	85–105 feet	Lower slope grade no. 1: Hardwoods, 6 M to 7 M. Yellow pine, 9 M to 10½ M. White pine and hemlock, 12 M to 14 M.
Productive, below average, IV.	60–85 feet	Lower slope grade no. 2: Hardwoods, 3 M to 5 M. Yellow pine, 4 M to 8 M. White pine and hemlock, 6 M to 12 M.
Nonproductive, V	Less than 60 feet	Upper slope and ridge: Hardwoods, 1 M to 2 M. Yellow pine, 1 M to 3 M.

CLASSIFICATION OF STANDS FOR SILVICULTURAL TREATMENT

RELATIVE DESIRABILITY OF SPECIES

On pages 4–8 the southern Appalachian timber species have been listed in general order of relative silvicultural desirability as indicated by present knowledge. The logging history of the region has repeatedly proved that the relative commercial values of the different tree species are not stable. New developments have continually arisen to bring little-used species into economic importance. At present few of the region's forest tree species are without promise of commercial value. Since the extension of utilization is likely to go on indefinitely, the choice of species to be encouraged for future production should be based not so much upon present demand as upon growth rate, mature size, form, soundness, vigor, resistance to fire damage, freedom from insect enemies and from disease, and the technical properties of the wood. Trees having wood qualities adaptable to more than one type of use are in general those most likely to maintain a stable value.

The desirability of certain tree species varies with site conditions. Yellow poplar, for example, should not be favored except on relatively moist soil. Certain other species, such as scarlet oak, make good growth on a wide variety of sites but because of the inferior quality of their products, or for some other reason, should not usually be favored on good sites. Thus on the better sites scarlet oak should be discouraged in favor of such species as yellow poplar, northern white pine, red oak, or even black oak, but on some poorer sites it should perhaps be encouraged. Among individual stands the desirability of a given species varies with composition, density of stocking, and vigor. Each stand must be considered with the idea of best utilizing the potentialities of the area which it occupies. On better sites it is a mistake to permit land to be permanently held except by species that will grow rapidly and yield valuable products. Consequently intensive treatment is justified on the better sites.

Local circumstances often affect the desirability of certain species, particularly where a permanent wood-using industry is being supplied.

DESIRABILITY OF INDIVIDUAL TREES

In addition to the relative desirability of species and their relation to site conditions, which have been discussed, silvicultural operations are conditioned by the qualities of individual trees, such as thrift or vigor, soundness, and form. Whether the improvement operation is intended to increase the stand's commercial value or promise of commercial value or to afford better watershed and soil protection, it is desirable to remove weak and defective trees. The qualities of individual trees are determined by past history and by present position in the stand.

SPROUT GROWTH

It is generally believed that seedlings are silviculturally preferable to sprouts. While a sprout usually grows faster in the juvenile stages it does not have the sustained vigor of a seedling and is much more likely to rot at the base. In general, the larger the stumps the less desirable are the sprouts. Sprouts from stumps less than 2 inches in diameter are practically as desirable as seedlings; these may be termed "seedling sprouts." Of all the southern Appalachian species only basswood and chestnut produce successful sprouts from stumps of saw-log diameter. Chestnut, of course, is out of consideration because of the blight. Of the oaks, chestnut oak is the most prolific and persistent sprouter. Sourwood, dogwood, black gum, and sassafras are among the less desirable species that sprout prolifically.

DAMAGE, ABNORMALITY, AND DISEASE

Stand improvement involves the removal of trees affected by any injury that threatens to nullify or seriously reduce their value. Rot, broken branches, and open wounds along the trunk are common types of defect. A prevalent cause of open wounds is fire. This form of injury is always present in stands that have frequently been burned. Fire damage is so common, in fact, that in some stands all the trees are scarred and only the worst damaged ones can be designated for removal in improvement operations.

Any open wound, caused by either fire, logging, or the breaking of limbs by wind or ice, presents a chance for the entrance of decay and insects. Trees with large scars, such as are caused by repeated fires, are particularly undesirable. Even though a wound has healed over, it may first have served as the point of entrance of decay that has subsequently spread up the trunk from the wound. Any appearance of decay, such as rot in an unhealed scar or as fungous fruiting bodies (conks) on the trunk or branches, establishes good reason for removing a tree. Insect-infested trees and trees that bear considerable quantities of mistletoe or witches-broom should be removed.

Ice storms have been responsible for much breakage of tree branches and much bending or breakage of the trunks of small trees. Besides opening wounds into which rot may enter, severe ice breakage may ruin the form of a tree for utilization and retard its growth.

Serious abnormalities that affect the value of trees and constitute reason for removal include abnormal swellings, dead tops, abrupt crook or gradual bend (sweep), fork, and excessive limbiness. Trees

that have been left standing when those around them were cut frequently exhibit many small new branches (water sprouts) along the trunk. When these are not excessively numerous they do not usually constitute in themselves a reason for removing the tree. Most of them will be killed by the shade from the crown of the tree itself or those of its neighbors.

The southern pine beetle periodically becomes epidemic in the region and causes considerable damage. The death of scattered groups of pines can usually be attributed to attacks by this insect. Fading of the foliage and the presence of pitch tubes, but more especially the presence of winding S-shaped tunnels in the inner bark, are reliable indicators of infestation. Where insect infestation is involved, efforts directed toward the reduction of insect broods are the most important feature of cultural operations. Such reduction can be effected by felling and peeling infested trees and burning the bark and tops. This treatment should precede emergence of the adult insects. Under favorable conditions the southern pine beetle develops from egg to adult in 30 to 40 days.

Dead trees need not ordinarily be removed from the stand except where it is important to preserve scenic values, as along roads, or where an extreme fire hazard exists. The southern Appalachian forests now contain an unusual number of dead and dying trees—largely chestnut trees, victims of the chestnut blight (*Endothia parasitica*). The death of these trees opens up the crown cover just as if it had resulted from girdling. Liberation cuttings in stands containing many dead or dying trees may therefore be concentrated on the removal of the living defective trees of species other than chestnut. In places it may be necessary to make cleanings in dense clumps of chestnut sprouts that are threatening other small growth of desirable species.

VIGOR, GROWTH RATE, AND SUPPRESSION HISTORY

An estimate of vigor can be made by observing the general size, form, and luxuriance of the crown, the rate of growth, and (particularly in pines, hemlock, and other conifers) the length of the leaders. Many trees suppressed for a long time are unable to respond to release. These cases are usually apparent from the crookedness of the tree, the unhealthiness or thinness of the foliage, and the flattening of the crown on top.

Since one of the major purposes of stand-improvement work is to accelerate the rate of growth, only those trees should be left that have made or are capable of making good growth on the site. Differences in diameter growth rate are largely due to differences in the degree of competition to which the individual trees are subjected. The rate of diameter growth can be ascertained by the use of the increment borer, a tool specifically designed to remove radially a small cylinder of wood. For most species the number and width of annual rings can easily be determined from such a cylinder.

On the better sites, trees of the faster-growing species, such as yellow poplar and the pines, unless they are being severely crowded, usually have growth rings wider than one tenth inch. On the poorer sites uncrowded trees may show annual rings as narrow as one fifteenth inch.

As the stands grow older and the trees increase in size, competition between individuals becomes more severe and, unless reduced by thinnings, leads to reduction in rate of diameter growth. In second-growth stands, need of thinnings is generally indicated if the growth of the dominant trees during the last 10 years is less than that shown for the preceding decade. In making thinnings, the selection of trees to be left should be based largely upon the condition of the tree crown and its position in the crown canopy.

Large spreading trees with branches extending well down along the bole, even though vigorous, are undesirable both because of the low grade of their lumber and because of the excessive space they occupy.

SHRUBS, VINES, AND WEED TREES

Over extremely large areas that have been logged the establishment of a satisfactory stand of timber is a problem not because desirable tree reproduction is absent but because of the presence of dense shrub thickets, of spreading vines, or of commercially worthless tree species. Common shrubs and vines of the southern Appalachian region are listed in appendix C. Some of these neither grow large enough nor occur in sufficient quantities to do much damage to the tree stands; others are very injurious, but are not very widely distributed; still others constitute a most difficult reforestation problem over extensive areas.

In the last-mentioned class the worst are mountain-laurel and two large species of rhododendron: *Rhododendron maximum*, occurring at altitudes below those of the spruce type, and *R. catawbiense*, occurring within the range of spruce and sometimes at lower altitudes. Mountain-laurel and rhododendron, frequently growing together in dense thickets, constitute an evergreen barrier to reproduction even of shade-tolerant tree species. Tree seedlings penetrate such thickets only in scattered openings. Possibility of satisfactory tree reproduction is still more remote if unmerchantable trees have been left standing after logging. A further hindrance to seedling establishment is the acid soil condition characteristic particularly of rhododendron thickets. All told, laurel and rhododendron present a most difficult reforestation problem over large areas in the southern Appalachians. Numerous other common shrubs (indicated by boldface type in appendix C) commonly interfere with the reproduction of desirable trees, particularly on cut-over areas that have been burned. Shrubs that frequently obstruct the establishment of desirable timber stands are blackberry, huckleberry, sumac, and sweetfern on the drier sites, and the same with alder, hydrangea, and many others on moist soils. Tree seedlings ultimately spring up here and there in spite of the competition, but commonly so far apart that they develop into widespreading, limby trees such as do not produce commercial material.

Of the vines, grape is by far the most injurious. Dutchman's pipe does a good deal of damage locally, but is not so common or so destructive as grape. Grapevines frequently spread out over the tops of young second growth in patches of as much as one-fourth acre, bending the young trees over and ruining the stand.

Many small tree species, practically worthless commercially, frequently occur in sufficiently dense thickets to prevent the develop-

ment of desirable trees that may be present on the area. Such species, sometimes termed "weed trees", are indicated by asterisks in the tree list in appendix B. The most widespread and troublesome of these are sassafras, sourwood, silverbell, dogwood, and pin cherry.

STAND CONDITIONS

The classification of stand conditions adopted here, based on condition of overstory and understory, stocking, soundness, and desirability of species, is shown in tables 3, 4, and 5 (pp. 23, 25, and 29), together with the improvement measures recommended for each condition class.

The following definitions are given to facilitate the use of tables 3, 4, and 5:

Dominant canopy good refers to the percentage of dominant and codominant trees in the stand that are now (or will develop into) sound trees of merchantable quality. In the case of old growth a good dominant canopy has been defined as one that contains 75 to 100 per cent of such desirable trees. In the case of a young stand, a good dominant canopy is one containing 60 to 100 per cent of desirable trees.

Dominant canopy poor indicates a lower percentage of desirable trees in the dominant canopy than that implied by "dominant canopy good."

Good stocking of desirables in understory implies the presence of reproduction of desirable species distributed at the rate of at least one stem to every 15-foot square, or 200 trees per acre, when the trees are less than 15 feet high, and at the rate of at least 100 well-distributed trees per acre when the trees are more than 15 feet high.

a. **Competition of undesirables severe** implies that competition threatens to reduce the stocking of desirable species below that defined as *good*.

b. **Competition of undesirables not severe** implies that competition does not threaten to reduce stocking of desirable species below that defined as *good*.

Poor stocking of desirables in understory implies a stocking of less than 200 well-distributed desirables per acre for trees less than 15 feet high, or of less than 100 trees per acre for trees more than 15 feet high.

a. **Competition of undesirables severe** implies that competition precludes good stocking.

b. **Competition of undesirables not severe** implies that competition does not preclude good stocking.

In tables 3, 4, and 5 the term "old growth" applies to all stands containing an overstory of trees 15 inches or larger in diameter at breast height; "second growth" refers to stands in which the diameters of the dominant trees are prevailingly as large as 4.5 inches and less than 14 inches; and "new growth" refers to reproduction less than 4.5 inches in diameter.

Most stands contain a mixture of trees of different sizes and ages. Large openings created in the old-growth forest by cutting are usually occupied by dense thickets of new growth. This reproduction requires silvicultural treatment differing from that required by the reproduction in adjacent uncut or selectively cut old-

growth stands. The terms "overstory" (dominant canopy) and "understory" are used in the tables for each of the three primary classifications old growth, second growth, and new growth, although the terms refer to widely different size groups of trees. To avoid confusion this concept must be kept clearly in mind. In old-growth stands the dominant canopy (i.e., dominants and codominants) may consist of trees from 15 to 30 or more inches in diameter at breast height, and the understory may contain trees up to 14 inches or even larger in diameter. On the other hand new growth occupying openings on a heavily cut-over area may have a dominant canopy consisting of hardwood sprouts 6 or 8 feet tall, and a suppressed understory of white pine seedlings only 1 or 2 feet tall. The meanings of the terms "overstory" and "understory" as used in tables 3, 4, and 5, respectively, are illustrated in figure 3.

The first step in applying tables 3, 4, and 5 in the field is to determine whether the stand falls into the classification old growth (table 3), second growth (table 4), or new growth (table 5). The next step is to determine the quality of the trees in the dominant canopy. If this is found to be good the next step, in the case of a stand of second growth, is to determine the grade of competition existing in the stand. Observations as to the general thrift of the stand should be supplemented with increment borings in dominant trees, which will show whether crowding is reducing the growth rate appreciably. In general, dominant second-growth trees should have made as great an increase in diameter in the last 10 years as in the previous decade. If competition due to heavy stocking is found to be reducing the growth rate, the stand is classified as condition class 6, table 4. The treatment recommended involves thinning to release a certain number of the best dominant trees in the stand. If the observations and increment borings indicate that competition is retarding the growth rate but little, if at all, the stand is classified as condition class 7, for which no treatment is needed.

Certain condition classes, without doubt, occur more commonly than others. Forest exploitation in the southern Appalachians has involved heavy logging of the best stands, so that now large areas of highly productive land are occupied by new growth. On such areas condition classes 14 and 16 are most common. Over large areas that are relatively inaccessible, and in extensive stands of mediocre timber, only the best trees have been removed. In such forests condition classes 2 to 5, inclusive, occur most commonly.

The measures recommended in tables 3, 4, and 5 are general measures that must be modified to meet the requirements of each stand under consideration.

GENERAL IMPROVEMENT MEASURES

DEFINITIONS

The classification of forest-improvement measures used in this text follows closely definitions formulated in 1917 by a committee of the Society of American Foresters.[14] The definitions used here are as follows:

[14] Forest Terminology. Report of Committee on Terminology, Society of American Foresters. Jour. of Forestry, vol. 15, pp. 68–101. 1917.

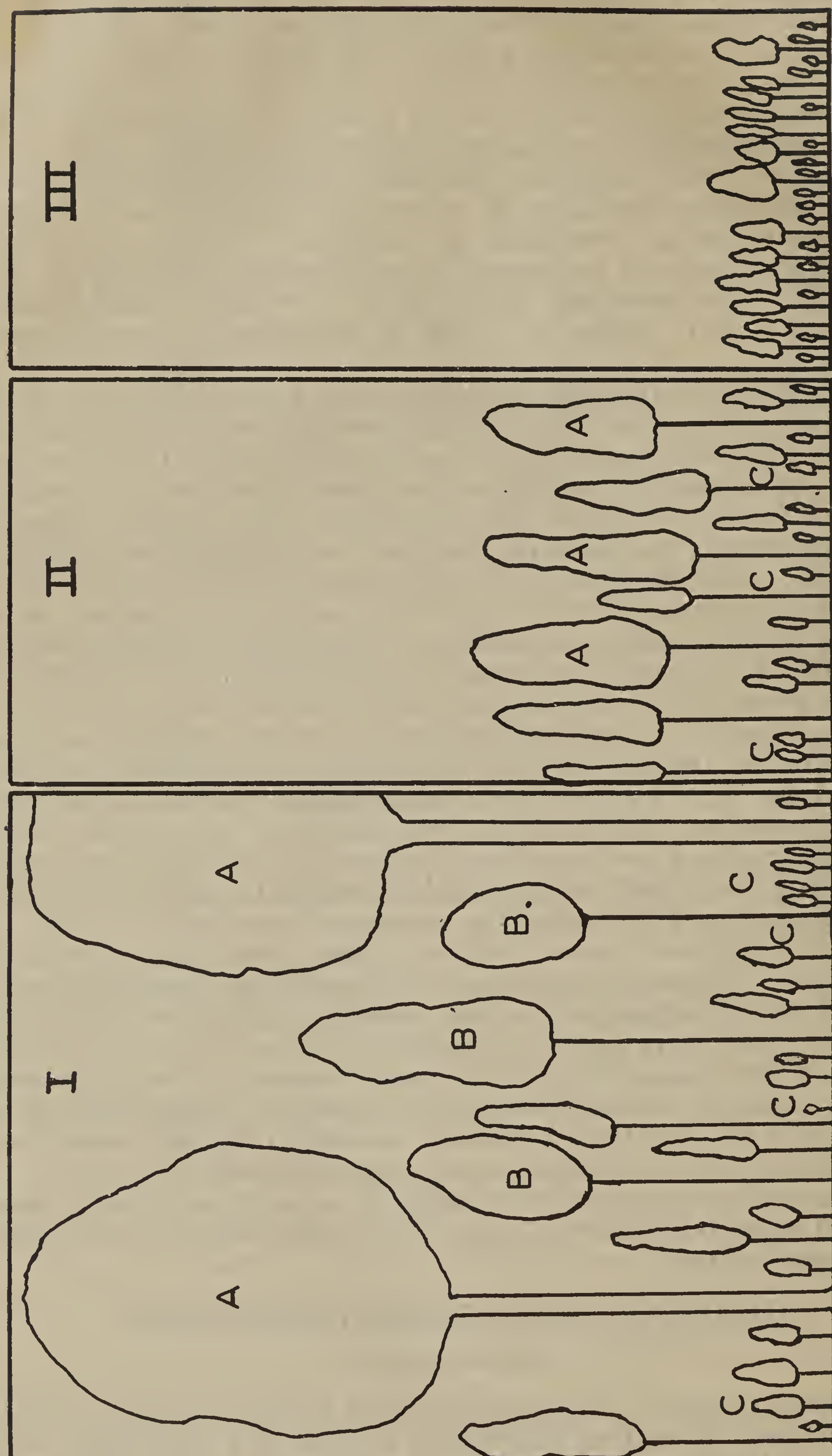


FIGURE 3.—Diagram illustrating various overstory-understory relationships. I. Overstory of old growth (A) with subordinate second growth (B) and new growth (C). Treatments outlined in table 3. II. Overstory of second growth (A) with subordinate new growth (C). Treatments outlined in table 4. III. New growth overtopping smaller new growth. Treatments outlined in table 5.

Cleaning. Cutting made in a stand not yet past the sapling stage (that is, in new growth) for the purpose of removing shrubs, vines, and trees of undesirable form or species that are injuring or are likely to injure promising trees. Synonym: Weeding.

Thinning. Cutting made in a dense immature (second-growth) stand after the sapling stage for the purpose of increasing the growth rate of the trees that are left and of improving the composition and quality of the stand. (The definition is extended to include the principle of improvement cutting.)

Improvement cutting. A cutting in a forest that has passed the sapling stage (second growth or old growth), the main object being to remove trees of undesirable form, condition, and species. It is always for the purpose of bringing the stand into better condition and composition for silvicultural management.

Liberation cutting. An improvement cutting in which desirable understory trees are freed from suppression by removal of undesirable overstory trees which may be either old growth, second growth, or new growth.

Underplanting. Setting out young trees, or sowing seeds, under an existing stand.

General improvement measures will be discussed in the following order: Liberation and improvement cuttings designed to improve the composition, quality, and reproduction of old-growth stands; thinnings and liberation and improvement cuttings designed to improve the growth rate, composition, and quality of second-growth stands; and cleanings and liberation cuttings designed to improve the composition and growing conditions of new-growth stands.

MEASURES DESIGNED TO IMPROVE OLD-GROWTH STANDS (TABLE 3)

IMPROVEMENT CUTTINGS

Improving the quality of old-growth stands presents the most difficult problem in the application of silviculture within the southern Appalachians.

Improvement cuttings, although designed particularly for the betterment of the larger diameter classes in the stand, in practice may also enable advance reproduction to develop and occasionally may even bring about the establishment of new reproduction. The correct application of improvement cuttings depends largely upon the operator's ability to make such a selection of individual trees for cutting as will insure maximum productivity of the available growing stock. The actual procedure to be followed in an improvement cutting depends upon the nature of the individual stand. The general practice consists in girdling or felling the poorer trees that are competing with sound, thrifty, and otherwise desirable individuals.

Costs of improvement cuttings, and likewise of liberation cuttings and thinnings, vary widely, the variation depending upon whether trees are cut and worked up into fuel wood or are merely girdled. Data are given in table 2 as to the labor required for girdling in comparison with that required for felling.

A widespread condition calling for improvement cutting is described in table 3 as condition class 4. Here the dominant canopy contains a high proportion of inferior trees and the understory con-

tains a poor stocking of desirables in severe competition with many undesirables. (See pl. 1.) This is one of the most difficult stand conditions to treat, because of the inadequacy of the growing stock. The best that can be done is to favor thrifty overstory trees of desirable species by an improvement cutting and to encourage such reproduction as exists under openings thus produced by a cleaning operation in the understory. (See heavy treatment for condition class 4, table 3.)

TABLE 2.—*Comparative labor requirements of girdling and felling hardwoods in cuttings for stand improvement*[1]

Average diameter at breast height (inches)	Trees removed per acre	Labor required per acre		Average diameter at breast height (inches)	Trees removed per acre	Labor required per acre	
		Girdling	Felling			Girdling	Felling
	Number	*Man-hours*	*Man-hours*		*Number*	*Man-hours*	*Man-hours*
18	5	0.3-0.7	0.7-1.2	8	10	0.3-0.5	0.6-0.85
	25	1.5-3	3.5-5.0		25	.75-1.5	1.75-2.5
	50	3.5-5	6.5-9.0		50	1.5-3.0	3.4-4.5
	75	5-7	9.5-12.0		100	3.5-5.5	7.0-9.0
	100	7-9	13.0-16.0		150	6.0-7.5	10.0-12.0
12	5	.25-.4	.5-.7		200	7.5-9.0	14.0-16.0
	25	.75-2.5	2.0-4.0				
	50	3.0-4.5	4.0-6.0				
	75	4.5-6.0	6.0-9.0				
	100	6.0-8.0	9.0-12.0				

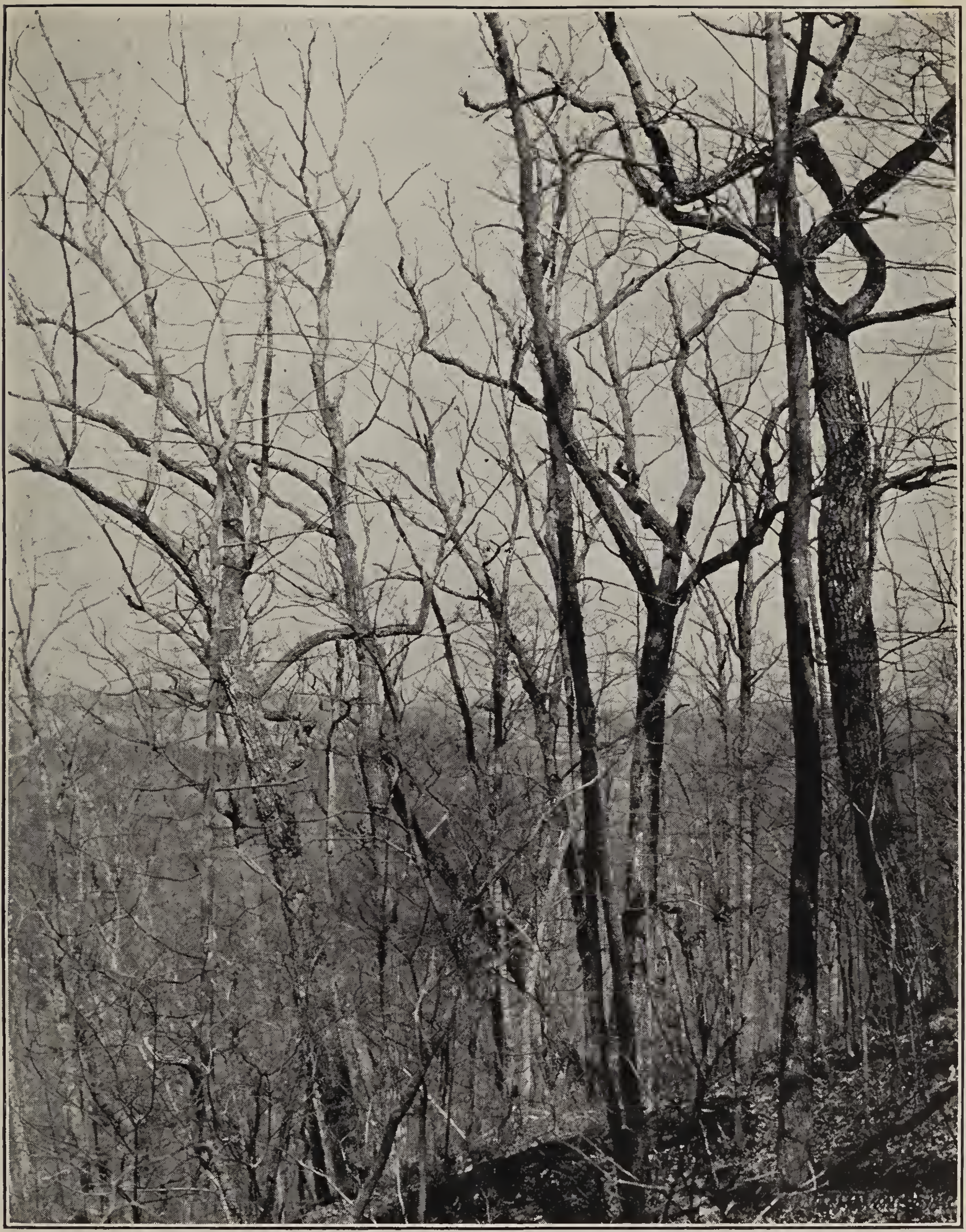
[1] Figures are based on meager data.

Old-growth stands, particularly those occurring in coves or in the northern hardwood type, are occasionally of very good quality, the overstory containing a high proportion of good trees (see pl. 2A). Such a forest represents the final objective of silviculture, although in existing cases the end result has been a matter of accident rather than design (condition class 1, table 3). If such stands are to be harvested in the near future, no treatment is necessary. If, owing to inaccessibility or other economic reasons, they are to remain for more than 10 or 15 years, an improvement cutting to remove unmerchantable overstory trees is recommended. This will help to maintain the waning vigor of the desirable overstory and will allow for the development of reproduction.

LIBERATION CUTTINGS

A not uncommon stand condition is that in which a decadent or highly defective overstory of old growth is suppressing an understory of desirable reproduction. If this desirable understory is relatively free of severe competition from inferior species in the understory (condition class 3), a liberation cutting alone is sufficient. If the desirable understory is in severe competition with inferior undergrowth (condition class 2, table 3), a cleaning should be combined with the liberation cutting.

The combination of a liberation cutting with a cleaning is particularly applicable on logged lands where stands of new growth free of overstory shading (condition classes 14–17, table 5) are intermingled with stands in which new growth occurs as an understory shaded by the residual defective overstory (condition classes 2–5, table 3).



Old-growth oak-chestnut stand containing many undesirable trees in the overstory. The understory contains but few desirable trees, which are in competition with many undesirables such as sourwood and dogwood. Needed treatment consists in an improvement cutting to favor the best individuals in the overstory and a cleaning to release understory trees in the openings produced by the improvement cutting.

A, Old-growth cove hardwoods with a dominant canopy of excellent quality (condition class 1, table 1). If such a stand is to be cut soon no treatment is necessary. If cutting is to be delayed beyond 10 years, unmerchantable trees should be cut or girdled to make way for the development of reproduction. B, The defective black oak has been girdled and the axman is girdling a dogwood with a wide-spreading crown. The leaf litter is being removed and the soil will be cut up with fire tools.

EXAMPLE OF CLEANING COMBINED WITH LIBERATION CUTTING

Following a timber sale in 1929 on Bee Branch of Little Buck Creek, Pisgah National Forest, N.C., a combined liberation cutting and cleaning operation was carried out on 73 acres during the summer of 1931. Before the sale the stand had averaged about 5,000 board feet per acre in age classes ranging from 20 to 120 years, the bulk of the timber being in the oldest age class. There had been no recent fire over the area, and satisfactory reproduction was present over much of it. The timber sale removed material down to a breast-height diameter limit varying with species from 10 inches to 16 inches. All chestnut was designated for cutting.

After the sale there was present on the area an average of 800 board feet per acre, about 30 percent of which was in yellow poplar and red oak seed trees. Occasional large unmerchantable hickories, and black gums, sweet birches, and red maples were left scattered over the area, along with defective trees of merchantable species.

In the liberation cutting, which was confined to coves and lower slopes, these undesirable holdovers and also the taller pole-sized trees of undesirable species were girdled or felled. Heavy cleanings were made wherever undesirable vegetation was crowding desirable reproduction. In the liberation cutting 92 trees 3 inches and larger in diameter at breast height were girdled or felled per acre, and in the cleaning 171 stems per acre were cut. The combined operations required 7-man hours per acre. The area was left completely stocked with good reproduction free to grow.

The crew included a regular warden as foreman and 4 or 5 axmen. The district ranger worked with the crew for the first half day to instruct them. The area was covered by narrow strips following the contours. The foreman worked in the center of this strip, for ease in supervising the cutters. He acted as axman himself except when advising the others. The liberation and cleaning were done in one trip over the area.

BETTERMENT BY REPLACEMENT

In old-growth (or second growth) stands with a highly defective overstory, if the understory is absent or is made up of undesirable reproduction, measures for stand betterment must be directed toward the replacement of the present stand by new reproduction.

Stands containing light-seeded species afford an unusual opportunity for such improvement. These stands occur in such forest types as white pine-hardwood, yellow pine-hardwood, and cove hardwood. Practically all the light-seeded species are of good quality and are usually of more rapid growth than the heavy-seeded species with which they are associated. In many instances the light-seeded species such as white pine, yellow poplar, and the yellow pines have been culled out so that they are less fully represented now than formerly. Treatment should be designed not only to improve the composition and growth rate of the existing stand but to increase the proportion of the light-seeded species in the mixture. Conditions favoring natural reproduction of these species can be produced by exposing and scarifying the mineral soil on small spots and girdling the overstory above the spots. This work should be performed in late summer, before seed fall.

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Plate 2B illustrates one method recommended for this operation. Each crew consists of 4 men, 1 man with an ax to choose and girdle large, defective overstory trees and such smaller inferior understory trees as may be heavily shading areas on which reproduction is to be induced, and 3 men using Rich or council fire rakes to follow the axman, rake the litter and small vegetation from the areas overtopped by the crown spread of the girdled trees, and chop up the exposed soil. The leaf litter raked back should not be allowed to lie around the edge of the spot in windrows but should be scattered back 6 or 8 feet from the treated area. This reduces the chances of the area being covered again by wind-blown leaves. An hour's work by such a 4-man crew is sufficient to prepare 3 or 4 spots averaging 25 to 35 feet in diameter. Six to eight such spots per acre constitute a light treatment and 12 to 16 a heavy treatment. The diameter of the opening in the crown canopy should not be less than 25 or 30 feet. Smaller openings close too quickly, with the result that any reproduction established is prevented from occupying a dominant place in the crown canopy.

In tables 3 and 4 a footnote indicates condition classes in which soil-scarification methods should be considered if the stand contains seed trees of desirable light-seeded species.

Heavy seeds such as nuts and acorns are not so capable of wide dispersal as are the light seeds of such species as the pines, ashes, and yellow poplar. As a rule heavy seeds require a covering of leaf litter for satisfactory germination and early survival. In stands containing only heavy-seeded species, the replacement of undesirable trees with new reproduction depends largely upon (1) maintaining a greater number of seed trees than would be necessary in the case of light-seeded species, (2) maintaining a layer of leaf litter on the ground, and (3) removing undesirable understory vegetation that would interfere with the development of new reproduction. Replacement may be expedited by actually planting seeds or seedlings in openings large enough to insure that the young trees will be free from interference by large or small vegetation. For this purpose it is best to use species that are at least moderately tolerant of shade. (See list of species in order of tolerance, in appendix D.)

TABLE 3.—*Stand-improvement measures*[1] *for old-growth stands*[2] *forming either a continuous or a broken overstory*[3]

Stand conditions			Condition class	Suggested treatment: Light	Suggested treatment: Heavy
Dominant canopy **good** (75–100 percent desirable trees).	Stocking and condition of understory not important to improvement of stand at present time.		1	**Improvement** and **liberation** (advised only if logging is to be deferred beyond next decade): Girdle or cut worst of undesirables in overstory, to release desirable second growth or reproduction or provide for new reproduction.	**Improvement** and **liberation** (advised only if logging is to be deferred beyond next decade): Girdle or cut all of undesirables in overstory, to release desirable second growth or reproduction.
Dominant canopy **poor** (0–74 percent desirable trees).	**Good** stocking of desirables in understory.	Competition of undesirables in understory **severe.**	2	**Liberation:** Girdle or cut especially wide-spreading undesirables in overstory that are overtopping best of desirables in understory. **Improvement:** In openings produced by liberation, girdle or cut undesirables of pole size that overtop or crowd best of desirables of pole size. **Cleaning:** In openings produced by liberation, cut enough undesirables in understory to release best desirables.	**Liberation:** Girdle or cut all of undesirable overstory. **Improvement:** In openings produced by liberation, girdle or cut all undesirables of pole size. **Cleaning:** In openings produced by liberation, cut all undesirables in understory that are competing with desirables.
		Competition of undesirables in understory **not severe**.	3	**Liberation:** Girdle or cut especially wide-spreading undesirables that are overtopping desirables in understory.[4]	**Liberation:** Girdle or cut all undesirables in overstory. **Cleaning:** Cut all competing undesirables in understory.[4]
	Poor stocking of desirables in understory.	Competition of undesirables in understory **severe**.	4	Light treatment inadequate	**Improvement:** Girdle or cut undesirables in overstory. **Cleaning:** Girdle or cut undesirables in understory to favor desirables, if any are present. **Spot clearing** in understory, with supplementary **planting.** Later, release cuttings probably necessary.[4]
		Competition of undesirables in understory **not severe**.	5	**Improvement:** Girdle or cut wide-spreading undesirables in overstory, particularly those of light-seeded inferior species.[4]	**Improvement:** Girdle or cut all undesirables in overstory.[3]

[1] Applicable to sites I–IV, inclusive (see pp. 10–12), in all forest types except spruce.
[2] Stands of trees 15 inches or more in diameter at breast height.
[3] For treatment of second-growth or new-growth stands occupying openings of more than one-fourth acre in broken old-growth canopy, see tables 4 and 5.
[4] Where seed-bearing trees of desirable light-seeded species are present in the overstory, soil scarification under the girdled trees or in openings left by cutting is suggested. (See pp. 21–22.)

MEASURES DESIGNED TO IMPROVE SECOND-GROWTH STANDS (TABLE 4)

THINNINGS TO IMPROVE GROWTH RATE AND COMPOSITION OF DENSELY STOCKED STANDS

Ordinarily, stands for which thinnings are recommended are fully stocked stands containing a high proportion of desirables in the dominant canopy (condition class 6, table 4) (pl. 3). If a series of thinnings at 5- or 10-year intervals is contemplated the rule is to thin lightly, removing the weaker trees, the defectives, some of the trees of less desirable species, and only enough of the dominant and codominant trees of good species to insure that the crown development (upon which depends the diameter growth) of those left will be unimpeded during the period before the next thinning.

When an early second thinning is not contemplated, the thinning should be heavier than this. The method recommended is to reserve from 50 to 75 crop trees per acre in light treatment, from 75 to 125 per acre in more intensive treatment, and perhaps 150 to 250 per acre in treating dense second growth such as some old-field stands of the yellow pines, white pine, or yellow poplar. Immediately around these crop trees the stand should be thinned rather heavily, so that surrounding crowns will not close in on and interfere with the development of the crop trees for many years to come. Where widespreading, defective trees are removed, large openings can not, of course, be avoided; it is to be expected that such openings will later be partly filled by reproduction.

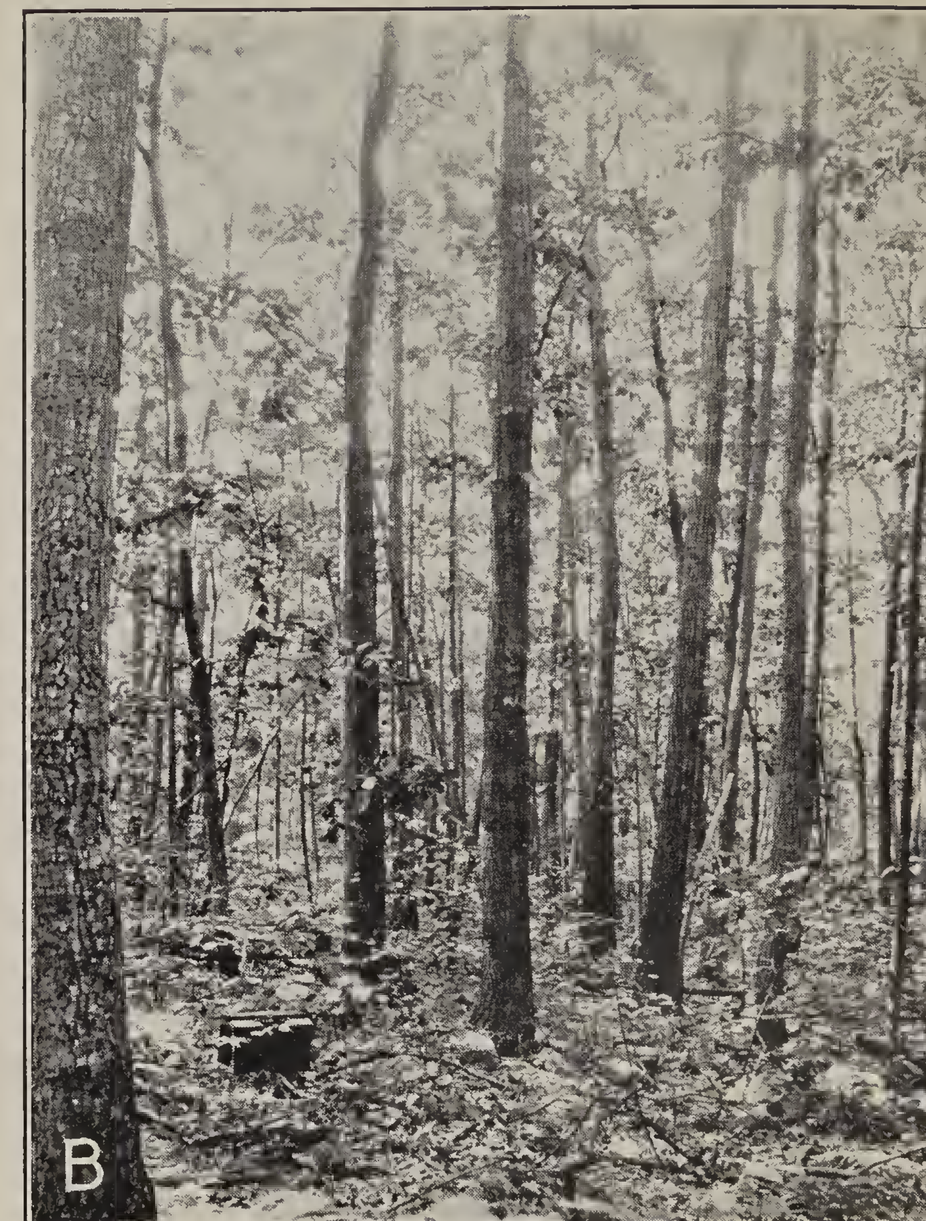
EXAMPLE OF THINNING

An experimental thinning made in a 40-year-old stand of yellow poplar near Cranberry, N.C., is illustrated by plate 4. The stand contained 428 trees per acre, of which 238 were yellow poplars ranging up to 20 inches in diameter and up to 90 feet in height. Of the best dominant and codominant poplars, 84 per acre were selected to be released from competition. To effect this release 102 trees per acre were cut, ranging from 6 to 21 inches in diameter at breast height. Of these 88 were yellow poplars. The released trees were left free to grow for a long time before their crowns once more became crowded. Such operations correspond to the heavy treatment suggested for condition class 6 (table 4).

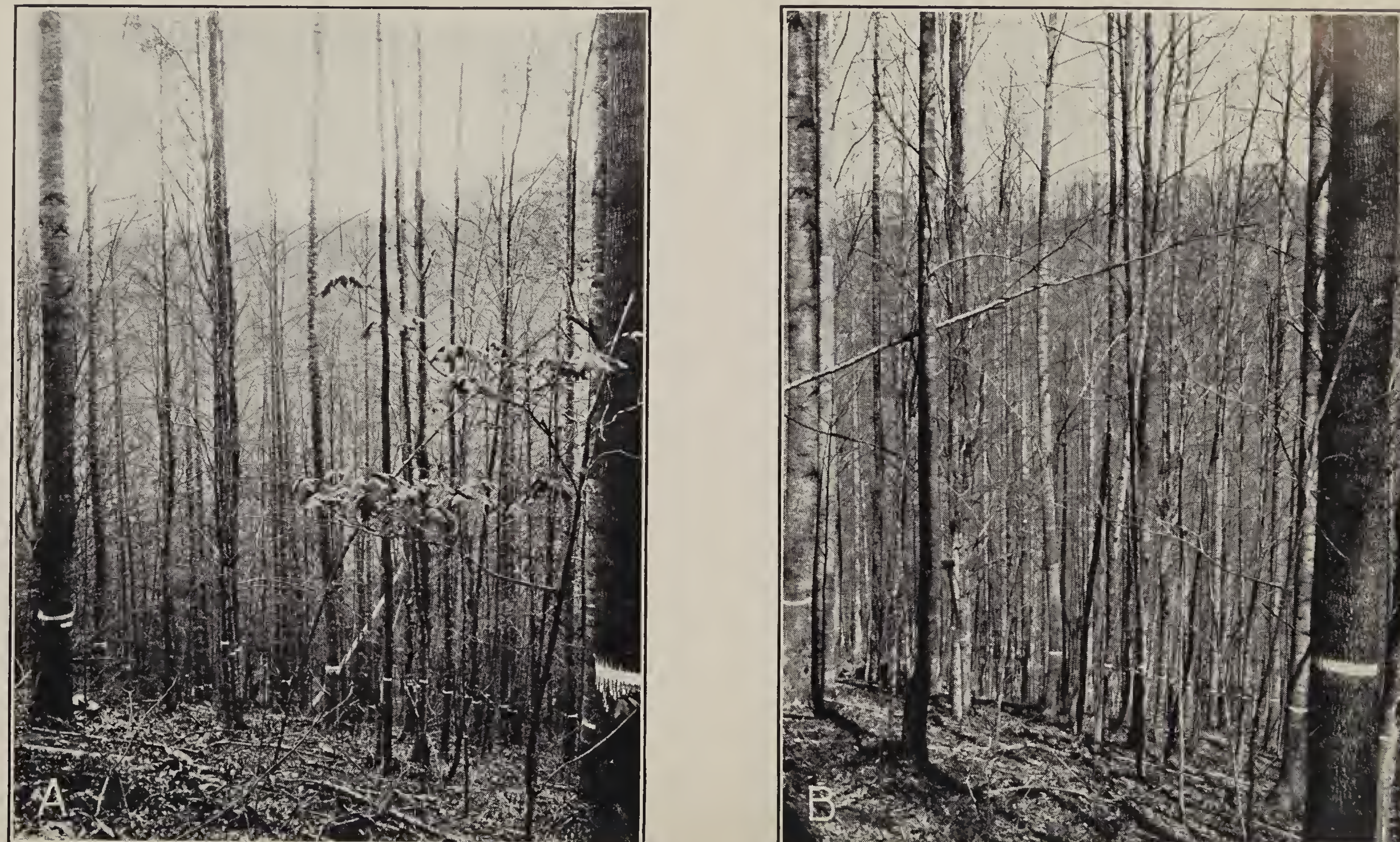
LIBERATION AND IMPROVEMENT CUTTINGS IN OVERSTORY, COMBINED WITH CLEANINGS IN UNDERSTORY

The overstory of second-growth stands in the southern Appalachians commonly contains a high proportion of trees of undesirable species and of inferior trees of good species. An understory of desirable reproduction is frequently present, which if released by the removal of poor overstory trees would subsequently take a place in the overstory. Such a transition would thus greatly improve the composition of the stand (condition classes 8 and 9, table 4).

In liberation cuttings good judgment is required on the part of the operator selecting trees for removal. If the development of the desirable understory reproduction is jeopardized by severe competition from undesirables in the understory (condition class 8, table



A, Second-growth black cherry in the northern hardwood type on the Monongahela National Forest, W.Va. The dominant canopy is good. A few increment borings are necessary to determine whether density of stocking is slowing the growth rate appreciably. If so, the stand may be classified as condition class 6, and a thinning to favor the best trees is advisable. If the growth rate is well maintained, the condition class is 7 and no improvement measures are necessary. B, Thrifty second-growth stand of mixed oaks containing a high proportion of desirable trees in the dominant canopy (condition class 6), near Wardensville, W.Va. In stands such as are shown here and in A the understory is of minor importance. The treatment needed is a thinning to give the best dominant trees full opportunity for growth.



A 40-year-old stand of yellow poplar near Cranberry, N.C.; A, before and B, after thinning. "Crop trees" (marked with white bands) numbering 84 per acre were released from competition by the cutting of 102 trees per acre.

TABLE 4.—*Stand-improvement measures*[1] *for second-growth stands*[2] *forming either a continuous or a broken canopy,*[3] *free of old-growth overstory*

Stand conditions			Condition class	Suggested treatment: Light	Suggested treatment: Heavy
Dominant canopy **good** (60–100 percent desirable trees).	Stocking and condition of understory not important to improvement of stand at present time.	Competition due to heavy stocking reducing growth rate of desirable overstory trees.	6	**Thinning:** Completely release 50 to 75 of best dominants per acre.	**Thinning:** Completely release 75 to 125 of best dominants per acre.
		Little if any unfavorable competition.	7	No treatment needed.	No treatment needed.
Dominant canopy **poor** 0–59 percent desirable trees).	**Good** stocking of desirables in understory.	Competition of undesirables in understory **severe.**	8	**Liberation:** Girdle or cut wide-spreading undesirables in overstory. **Cleaning:** In openings produced by liberation, cut undesirables in understory competing with best desirables.	**Liberation:** Girdle or cut all undesirables in overstory. **Cleaning:** In openings produced by liberation cut undesirables in understory competing with desirables.
		Competition of undesirables in understory **not severe.**	9	**Liberation:** Girdle or cut wide-spreading undesirables in overstory that are overtopping desirables in understory.[4]	**Liberation:** Girdle or cut all undesirables in overstory.[4]
	Poor stocking of desirables in understory.	Competition of undesirables in understory **severe.**	10	Light treatment inadequate.	**Improvement:** Girdle or cut all undesirables in overstory. **Cleaning:** Girdle or cut undesirables in understory to favor desirables, if any are present. Under openings in overstory **clear spots** 10 to 12 feet in diameter and **plant.** (This method is particularly applicable to sites favoring fast growers such as white pine and yellow poplar.)[4]
		Competition of undesirables in understory **not severe.**	11	**Improvement:** Girdle or cut widespreading undesirables in overstory, particularly those of light-seeded inferior species.[4]	**Improvement:** Girdle or cut all undesirables in overstory. Supplementary **planting** under openings thus produced.[4]

[1] Applicable to sites I–IV, inclusive (see pp. 10–12), in all forest types except spruce.
[2] Stands of poles 4.5 to 14 inches in diameter at breast height.
[3] For treatment of new-growth stands occupying openings of more than one tenth acre in broken second growth, see table 5.
[4] Where seed-bearing trees of desirable light-seeded species are present in the overstory, soil scarification under the girdled trees or in openings left by cutting is suggested. (See pp. 21–22.)

4), a cleaning under the openings produced by the liberation cutting is necessary. In the cleaning operation the tops of trees 3 inches or less in diameter should be lopped off or should be partially cut and bent over. The lopping or bending point should be fully 2 or 3 feet below the tops of the crowns of the better trees left, so that the latter will be enabled to keep ahead of the sprouts of the trees cut and eventually shade them out. Trees more than 3 inches in diameter should be girdled or cut. Girdling should remove a chip 1 or 2 inches deep. Girdling is cheaper than cutting for the larger trees, and tends to reduce sprouting.

The cost of liberation cuttings depends upon the methods used to dispose of the trees, the number of trees disposed of per acre, their sizes, and the brush and slash conditions on the area. Table 2 indicates the relation between diameter and labor requirement of girdling and felling.

In second-growth stands, liberation cuttings are not strongly differentiated from improvement cuttings. In the case of a poor overstory with desirable reproduction beneath, an improvement cutting fulfills the same purpose as a liberation cutting. In some stands the overstory is so worthless that the future value of the stand depends absolutely upon replacement of the overstory by trees of good species and good form, wherever possible. In such a case the distribution of desirable reproduction in the understory determines what portions of the overstory are to be removed and the cutting is a true liberation. On the other hand, an overstory may be classified as poor but still contain a sufficient number of desirable trees to form a light stand. In such a case the cutting is principally for the purpose of improving the growing conditions of the good overstory trees and is a true improvement cutting, although it may release some desirable reproduction and thus serve as a liberation cutting also.

EXAMPLE OF LIBERATION CUTTING IN SECOND GROWTH

In the fall of 1931 an experimental liberation cutting was made on 2⅓ acres of the Mulky Creek watershed on the Cherokee National Forest, Ga. An overstory of inferior second-growth hardwoods was shading a good stand of white pine reproduction averaging 2,500 stems per acre, ranging from 1-year seedlings to 15-year-old saplings. The cutting removed an average of 153 hardwoods per acre. These ranged from 4 to 20 inches in diameter at breast height, averaging 6 or 7 inches. About half the number were girdled by chopping out a ring of chips 2 inches wide about 2½ feet above the ground. The remainder were girdled and poisoned with a special tool that makes it possible to perform both operations at the same time. Costs averaged slightly less for the latter method. This operation, in which skilled labor was used, required about 4 man-hours per acre. An examination made at the end of the first growing season following the treatment showed that the rate of height growth of the liberated white pines had increased decidedly. The poisoned trees had fewer and smaller sprouts than those that had been girdled but not poisoned. Girdled or poisoned trees were dying rapidly.

MEASURES DESIGNED TO IMPROVE NEW-GROWTH STANDS (TABLE 5)

CLEANINGS TO IMPROVE GROWTH RATE AND COMPOSITION OF DENSELY STOCKED STANDS

Occasionally a dense growth of desirable reproduction becomes established after heavy logging. As the stand grows older, severe competition due to the density of stocking may reduce the growth rate of even the dominant trees. More commonly, the dense stand of tree sprouts and seedlings, shrubs, and vines that develops after cutting consists mainly of undesirable species. Usually enough good trees of the better species are scattered through this growth to stock the area if they are not crowded out or shaded out by undesirable trees or shrubs. Both these conditions are included in condition class 12, outlined in table 5. Cleanings in young stands such as those just described usually constitute the most valuable treatment that can be applied during the entire life of the stand.

In cleanings it is frequently necessary to choose crop trees—that is, trees reserved for final harvest when mature—from sprout clumps of desirable species. Sprouts should not be selected as crop trees unless they originate from stumps less than 2 inches in diameter. Among several sprouts growing from one stump, selection should be made of the largest sound one in the most nearly vertical position. Of the others, only those need be removed that are impeding the growth of the crop tree or appear likely to do so. In cases in which two sprouts originate at the same point, if one of the sprouts is cut and the other is left butt rot is very likely to develop in the remaining stem within the next 15 or 20 years. Either both stems should be left or both should be cut.

A good method of removing sprouts around a sprout chosen as a crop tree is to sever them just below the crown. This restricts subsequent sprouting to a minimum and reduces danger of decay entering the crop tree from the point of cutting.

Where vines are injuring desirable young tree growth they should be severed. Complete protection from vines would of course mean not only one cutting but repeated returns to cut back the sprouts; a single treatment, however, if complete, is very beneficial.

Where shrubs, herbaceous vegetation, or vines are found competing with desirable tree seedlings in the understory, the condition falls within condition class 14, and cutting away the undesirable vegetation constitutes a cleaning in the understory such as is referred to in table 5.

Ability to recognize tree species during their early stages is essential to good cleanings, especially in species mixtures so complex as those found in the southern Appalachians. In addition, a knowledge of the characteristics of the individual species and the relative desirability of the species from the silvical and economic standpoints is necessary.

In cleaning, no more trees should be cut than are necessary to free the desired trees from competition. Where the less desirable individuals are not actually overtopping the desirable trees or severely restricting the lateral development of the crowns of desirables, they should be left as trainers for the latter and to keep the ground covered. Most of them will be shaded out later by the better trees. The density of the stand that should be left depends

upon site quality and upon the percentage of good trees in the stand. For well-established reproduction of desirable species, satisfactory stocking has been set at one good tree to every 15-foot square, or about 200 trees per acre.

This standard of stocking is not advanced as one that can be realized on the average cut-over area in the southern Appalachian region. Studies by the Appalachian Forest Experiment Station (reported in U.S. Dept. Agr. Tech. Bul. 250) of unburned second-growth areas in the region have shown an average stocking of desirables much below this standard. Neither do the recommendations made in this publication mean that on an area where the stocking of desirables is below this standard all trees of undesirable species should be removed. In such a case sound, well-formed, and well-spaced trees of intermediate or even of poor species should be left in such numbers as to make the density of stocking approximate that of the standard.

If the trees to be released are several feet high the competing vegetation can be lopped off below the level of the tops of these trees. Instead of being completely severed it can be partly cut and then bent over. Sprouts from trees eliminated by the latter method tend to be less vigorous.

The machete is useful for cutting trees or shrubs 1½ inches or less in diameter, and the brush hook for stems up to 3 inches in diameter. For larger trees the ax should be used.

The cost of cleanings varies greatly with the condition of the stands treated and with the thoroughness and efficiency of the work.

LIBERATION OF DESIRABLE UNDERSTORY OVERTOPPED BY UNDESIRABLE NEW GROWTH

Another condition common in young stands is described in table 5 as condition class 15. Here an overstory of undesirable new growth (frequently sprouts) is overtopping an understory of desirable seedlings. A liberation cutting removing the inferior overstory is essential to stand improvement.

Instances in which desirable tree reproduction occurs as an understory to rhododendron and laurel thickets fall within condition class 15. If the reproduction is released by cutting it is likely to be subjected anew to competition by laurel or rhododendron sprouts from the cut stumps. Often the latter are too far away from the trees to menace them, however, owing to the fact that both laurel and rhododendron commonly grow in wide-spreading clumps the bases of which are separated by a space of 5 or 10 feet or even more. Where suppressed tree seedlings are found among rhododendron and laurel they can sometimes be released by cutting or lopping back only those parts of the clumps that are nearest them.

EXAMPLE OF LIBERATION CUTTING IN NEW GROWTH

Near Lookingglass Rock, Transylvania County, N.C., a heavy stand of reproduction of yellow poplar and other desirable species appeared after a severe burn in 1916, but was soon overtopped by a dense cover of sumac, chestnut, and silverbell. In 1924 this undesirable cover was 10 to 25 feet high, and the yellow poplars were only 2 or 3 feet high. In that year the chestnut, the silverbell, and

A, Dense thicket of new growth after a burn on a clear-cut cove hardwood area on the Pisgah National Forest, N.C. Poor dominant canopy of silverbell, sumac, and chestnut sprouts 10 to 25 feet high, suppressing a desirable understory of yellow poplar 2 to 3 feet high. The same stand as affected by a cleaning operation is shown in B and in plate 6.
B, Stand shown in A after cleaning operation removed silverbell and chestnut sprouts. The thin-crowned sumac was not considered a serious competitor, and much of it was left standing.

Stand shown in plate 5, 4 years after the cleaning operation. The cleaning resulted in definite establishment of the desirable yellow poplar.

PLATE 7

Check dams across a small gully. These were constructed entirely of local material. Such check dams help to prevent local floods and to prevent further scouring of gullies and washes.

PLATE 8

A, Brush fencing on open slope to control erosion and aid in restoring cover. Such barriers should be supplemented with planting. B, Loose rock check dams in mountain stream. C, Log cribbing to catch rock fragments and other eroded material washed down from denuded hillside.

TABLE 5.—*Stand-improvement measures*[1] *for new-growth stands*[2] *on areas of more than one-tenth acre free of old-growth or second-growth canopy*

Stand conditions			Condition class	Suggested treatment: Light	Suggested treatment: Heavy
Dominant canopy **good** (60–100 percent desirable trees).	Condition and stocking of understory not important to improvement of stand at present time.	Competition due to heavy stocking reducing growth rate of desirable overstory trees.	12	**Cleaning:** Completely release 50 to 100 of best desirables per acre.	**Cleaning:** Completely release 100 to 150 of best desirables per acre.
		Little if any unfavorable competition.	13	No treatment needed	No treatment needed.
Dominant canopy **poor** (0–59 percent desirable trees).	**Good** stocking of desirables in understory.	Competition of undesirables in understory **severe.**	14	**Liberation:** Cut undesirables in dominant canopy to free desirable understory trees. **Cleaning:** Completely release 50 to 100 of the best trees per acre.	**Liberation:** Cut undesirables in dominant canopy to free desirable understory trees. **Cleaning:** Completely release 100 to 150 of the best trees per acre.
		Competition of undesirables in understory **not severe.**	15	**Liberation:** Cut undesirables in dominant canopy to free desirable understory trees. **Cleaning:** Completely release 50 to 100 of the best trees per acre.	**Liberation:** Cut undesirables in dominant canopy to free desirable understory trees. **Cleaning:** Completely release 100 to 150 of the best trees per acre.
	Poor stocking of desirables in understory.	Competition of undesirables in understory **severe.**	16	Light treatment inadequate	**Cleaning,** combined with **clearing** in spots and **planting.** Subsequent cleaning of planted trees probably necessary.
		Competition of undesirables in understory **not severe.**	17	**Liberation:** Cut worst of undesirables in overstory. **Cleaning:** Completely release 50 to 100 of the best trees per acre.	**Liberation:** Cut all undesirables in overstory. **Cleaning:** Completely release 100 to 150 of the best trees per acre. Supplementary **planting** on cleared strips or spots suggested.

[1] Applicable to sites I–IV, inclusive (see pp. 10–12), in all forest types except spruce.
[2] Stands of reproduction up to 4.5 inches in diameter at breast height.

some of the sumac were cut on sample plots (see pl. 5), other plots being left untreated. In 1928 there were 203 unsuppressed yellow poplar trees per acre on the treated plots (see pl. 6) but only 22 living poplars per acre on the untreated plots.

MEASURES TO PREVENT EROSION AND TO PROMOTE ABSORPTIVE SOIL CONDITIONS

In the southern Appalachian region forest cover plays an important part in the regulation of stream flow and the control of erosion. If well maintained and protected from fire, it reduces run-off and holds the soil firmly in place, thus tending to minimize floods and to stabilize low-water flow. It is primarily due to this fact that large areas have been purchased in the region for national-forest purposes. In many parts of the region precipitation exceeds 80 inches a year and slopes are steep; here it is highly important that rapid surface run-off at times of heavy rains be prevented.

In countries where flood-control activities have gone much further than in America, watershed-protection measures supplemental to the maintenance of a continuous forest cover are in common practice.

One way to increase the absorption of water into the soil is to construct a series of ditches along the contours. Such ditches, by holding the water running off the surface, permit it to soak into the soil. The elevational difference between them should be determined more by steepness of slope and depth of soil than by rate of surface run-off. On steep slopes, and where the soil is thin, an elevational difference of 100 feet may not be too great. On gentle slopes and those with deep soils, the elevational interval between ditches may be 50 feet or less. Sections of the region where high surface run-off takes place during times of torrential rain need proportionally larger numbers of ditches per acre than those where surface run-off is normally light. The ditches on a given slope need not be continuous. In fact, a long ditch is less desirable than a series of short ones, because its outside embankment may fail and still worse run-off conditions result. As an extreme the ditches may take the form of a series of small pits or shallow holes scattered at random up and down the slope. When absorptive ditches are prepared in connection with stand-improvement work, the vegetative material cut should be placed in windrows below the ditch rather than above it.

Sooner or later the ditches fill with litter and detritus washed from the slopes above them. Most of this material is vegetable matter, the decomposition of which enriches the soil and adds to its water-absorptive capacity; consequently, instead of clearing out the old ditches it is advisable to prepare new ones.

Another method of assisting water absorption, retarding surface run-off in time of heavy rains, and controlling erosion, is to construct check dams, a series of steps in the bed of a small stream. The function of check dams is to catch and hold debris, to reduce the normal grade of the stream and thus reduce its velocity and silt-carrying capacity, to increase water percolation, to prevent channel cutting, and to promote tree and brush growth in the drainage channel.

Check dams need not be elaborately constructed. They can be built of logs, rock, and other material obtained locally. Each such

structure should, however, be firmly knit together so that it will not yield to the pressure of the water and soil behind it. (See pl. 7.)

Check dams are subject to the same physical forces affecting larger dams, and should be constructed with due regard for hydraulic principles. This entails care to prevent cutting around the abutments, to prevent undercutting at the foot of the dam, and to prevent internal stresses set up by the combined flow through and over the dam that may result in direct failure. The top of the dam should be lower in the middle than at the ends.

When the dams are made of rock, the stones should be so keyed together as to bind firmly and hold against pressure. Mere piles of loose small stones are inadequate to withstand large flows. Where the only stones available are small or cannot be made to fit tightly without the use of cement or some other binder, woven wire fencing should be used to hold them together. Where the dam need not be so much as 4 feet in height and the stream gradient is gentle, a loose rock and wire dam is adequate. Where the dam is to be more than 4 feet high, the stream gradient is steep, and maximum storage is desirable, a bound rock and wire dam is needed.

The construction of the first type of dam is shown in figure 4 (type A).[15] It is essentially merely a sackful of loose rock, the sack being made of the wire fencing, with a mat extending a short distance downstream to prevent undercutting.

The bound rock and wire dam is likewise simple of construction, differing from the type just described principally in that it is built in horizontal sections. First a length of the wire fencing is laid on the stream bed, with the upper end bent to form the upstream face. A series of tie wires (about no. 8 gage) are fastened to it, from 6 to 10 inches apart in a row and in rows about a foot apart, their ends protruding upward. Stones are piled on to a depth of from 8 to 12 inches. Another layer of woven wire is laid flat on this surface, fastened securely to the upstream face, and bound with the tie wires to the first layer. Its downstream end is bent downward and laced securely to the first layer. Another series of tie wires are fastened on this second layer of wire, and another layer of stones and wire are added and tied in place. This is repeated until the dam is completed. Such a dam is shown in figure 4 as type B. As in type A, the wire mat should extend several feet downstream to prevent undercutting. Plenty of tie wires should be used, so that each successive layer of woven wire is firmly tied to the one below. The rocks forming the core of the dam should be piled carefully, so that the least possible settling will take place.

Dams installed at the heads of minor drainages may be simpler and less firmly constructed than those placed farther down the streams, which will have to resist the pressure of heavier flows. For greatest effectiveness, the top of each successive dam should be at almost the same level as the bottom of the one next higher.

The "wire barrier" is a modified check dam now used in many places in the West. This is a length of woven wire fencing stretched at right angles across a stream and firmly anchored in place. The

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[15] The types of check dams described here and shown in figure 4 have been developed largely in Los Angeles County as a part of the flood-control measures used there. The work is under the direction of E. C. Eaton, with whose permission figure 4 is used.

manner of construction when pipe is used as a support is shown in figure 4 (type C). A mat of fencing to protect the barrier from undercutting is an essential feature. The fencing catches leaves, twigs, and other debris, and the basin behind it gradually fills with solids carried by the stream.

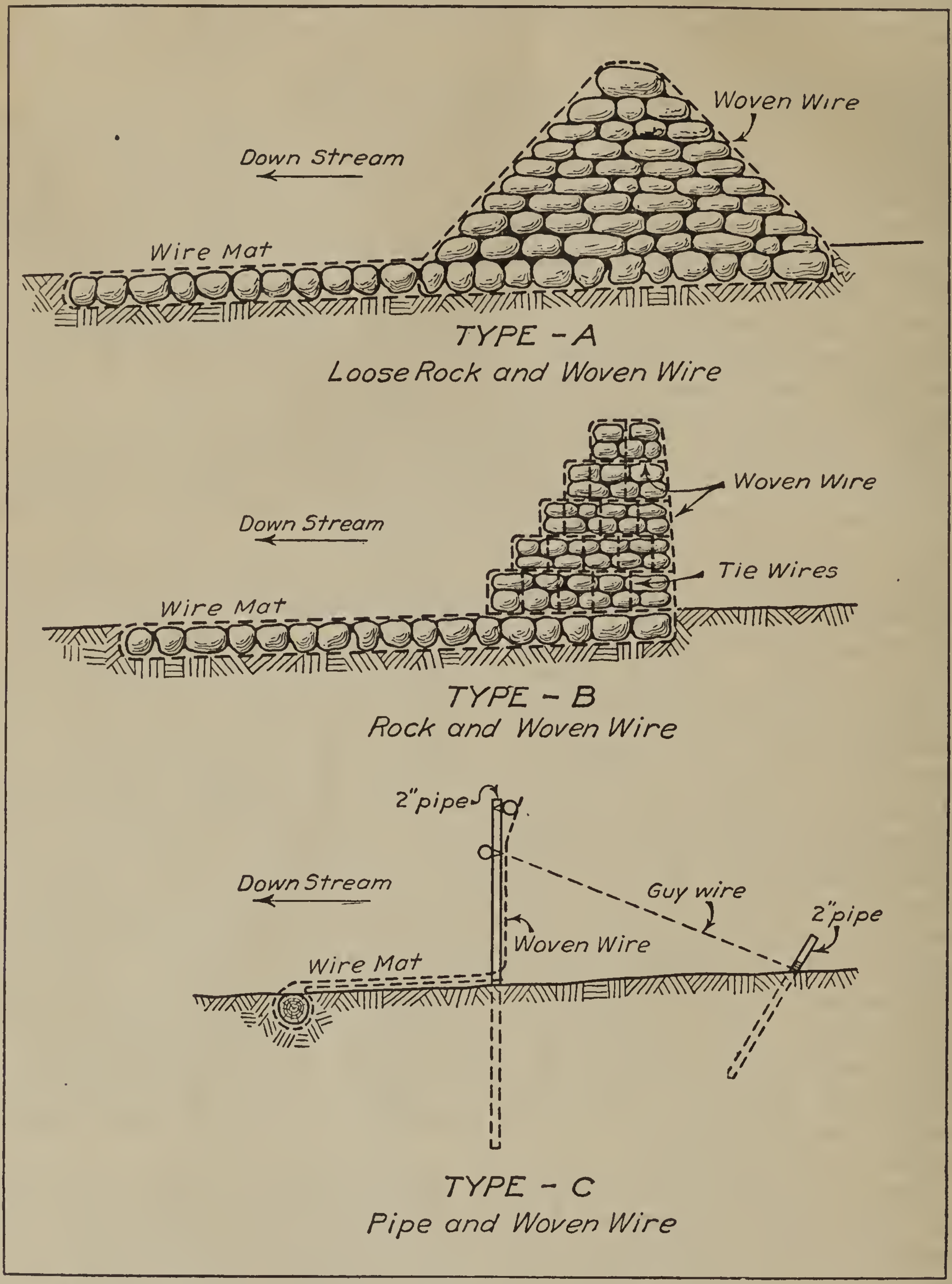

FIGURE 4. Typical forms of check dams constructed partly with woven-wire fencing.

Even simpler construction is adequate for check dams located at the very heads of small drainages where the catchment basins are slight in area or where only a few years' service is required. For example, brush may be piled in the beds of intermittent streams and held in place with rocks or a few shovelfuls of earth. When stronger structures are needed, cribbing can be used. When a cribbing is made

of logs and poles, these should be notched to permit spiking in place or binding with wire. The heaviest pieces should be used crosswise of the stream. The tie poles should be at least 6 feet long for dams 3 feet or less in height and 8 feet long for dams 4 or 5 feet high. Enough poles should be used to hold the cross-logs firmly in place. The topmost series of poles should be weighted with rock. In general, durable woods should be used wherever possible. It is permissible, however, to use a few green willow and poplar poles in each dam, because they will sprout and so help to bind the whole dam firmly together. (See pl. 8.)

Check dams have their greatest usefulness as temporary structures to catch eroded soil, especially on areas subject to gullying. In the Appalachian region gullying is likely to occur on old fields and overgrazed pastures and on lands denuded of vegetative cover by fire following logging or by smelter fumes and industrial gases. Where slopes are gentle and gullies not deeper than 3 feet, simple dams of brush weighted down with stones or earth serve adequately to check erosion. On old fields where both sheet erosion and gullying are general over the exposed surfaces, windrows of brush and other debris along contours serve to catch soil and to prevent excessive erosion until a vegetative cover is established. Low fences of brush or fagots held in place by stakes and weighted with rocks or poles function effectively if placed at sufficiently short intervals. On areas soon to be planted to grass or trees, bags of sand or of sod placed end to end across gullies retain much soil.

The detention basins behind check dams fill quickly if there is much erosion above them. The filled-in basins soon support a stand of herbaceous vegetation. For lasting benefit, they should be planted with trees. Cuttings of willows and poplar are particularly satisfactory for such planting, because they withstand sedimentation and thrive in the moist soil. Deep-rooted species such as sycamore are to be preferred to such species as hemlock and beech.

For erosion-control plantings in active gullies black locust is particularly recommended, because of the rapid growth and wide spread of its roots. On open lands the yellow pines, either pure or in mixture with black locust, afford the best prospects of success. Trees planted on eroding lands should be set closer together than is usual in forest plantations, because of the great need of quickly establishing a full stand. For severely eroding areas a spacing of 5 by 5 feet or even 4 by 4 feet is not too close. An irregular spacing is probably more effective in holding the soil than a regular one. Any shrubby or tree vegetation on severely eroding areas should be preserved, even though of species classed in general as undesirable.

APPENDIX A

SOUTHERN APPALACHIAN FOREST TYPES RECOGNIZED BY THE COMMITTEE ON FOREST TYPES, SOCIETY OF AMERICAN FORESTERS

The classification of tree-species associations into the six major forest types described in this publication is adequate in general for application of the stand-improvement measures herein outlined. For the analysis of special silvicultural problems, however, a more detailed classification may be necessary. Such a classification of forest types has been prepared by a committee of the Society of American Foresters.[1] The southern Appalachian types recognized by the committee, grouped under the "major forest types" outlined in this publication, are as follows, the serial numbers being those used by the committee:

SPRUCE

TYPE 5. PIN CHERRY

Composition.—Pin cherry pure or predominating.

Associates.—In the North principally aspen, largetooth aspen, paper birch, red maple, and red oak, either coordinate with or subordinate to the pin cherry. In the southern Appalachians yellow birch, red spruce, southern balsam fir, mountain-ash.

Occurrence.—Throughout the northern forest region at elevations above 600 feet in the North, 3,000 feet in West Virginia, and 4,500 feet in North Carolina. On well-drained soils from poor to good quality. In northern Pennsylvania covers large continuous areas, elsewhere more often in small patches.

Place in succession.—Short-lived pioneer type which originates on clear-cut or heavily burned areas. In the North succeeded by aspen, or by types of the northern hardwood or white pine type groups, or by the red oak-basswood-white ash type. In southern Appalachians, succeeded by red spruce-southern balsam fir type, red spruce type, or types of the northern hardwood group.

TYPE 16. YELLOW BIRCH-RED SPRUCE

Composition.—Yellow birch and red spruce predominating.

Associates.—In the North balsam, red maple, paper birch, northern white cedar, and occasionally white spruce; in the southern Appalachians southern balsam fir, yellow buckeye, beech, sugar maple, and mountain-ash.

Occurrence.—Northern New England and New York at low elevations on lower slopes and moist well-drained flats. In the southern Appalachians at elevations of 3,500 to 5,000 feet.

Place in succession.—Possibly climax on moist flats in North.

[1] Forest Cover Types of the Eastern United States: Report of the Committee on Forest Types, Society of American Foresters. Jour. of Forestry, vol. 30, pp. 451–498. April, 1932.

TYPE 18. RED SPRUCE

Composition.—Red spruce pure or predominating.

Associates.—Balsam fir, paper birch, yellow birch, sugar maple, beech, red maple, hemlock, white ash, mountain-ash. In the southern Appalachians southern balsam fir and yellow buckeye are added. [In West Virginia spruce-hemlock is a characteristic variant.]

Occurrence.—Northern New England, mountainous areas of New York, Pennsylvania, and southern Appalachians. Elevations from near sea level in eastern Maine and 1,500 feet in New York to 4,500 feet; above 3,200 feet in West Virginia, and above 4,500 feet in North Carolina and Tennessee. Moderately well drained to poorly drained flats but not true swamps, well-drained slopes though not on the best soils, thin-soiled upper slopes. On a wide variety of soils on abandoned fields and pastures. In New England and New York occupies large areas on flat land and in zones at higher elevations on the mountains. Less abundant in southern Appalachians.

Place in succession.—Probably near climax on moist flats and on thin-soiled sites at high elevations, in other locations tending to be replaced by such species as sugar maple and beech.

TYPE 19. RED SPRUCE-SOUTHERN BALSAM FIR

Composition.—Red spruce and southern balsam fir pure or predominating, associated in the lower altitudinal portions of the type with hemlock, yellow birch, and less frequently with beech, sugar maple, yellow buckeye, mountain-ash, and hawthorn.

Occurrence.—At elevations of over 4,500 feet in southern Appalachian Mountains and over 3,200 feet in Allegheny highlands of West Virginia on all exposures.

Place in succession.—Climax. Replaced after cutting and fire by yellow birch except at highest altitudes.

NORTHERN HARDWOODS

TYPE 12. SUGAR MAPLE-BEECH-YELLOW BIRCH

Composition.—Sugar maple, beech, yellow birch in different proportions sometimes with smaller and varying admixtures of basswood, red maple, hemlock, red oak, white ash, white pine, balsam fir, black cherry, paper birch, black birch, American elm, and red spruce. In the southern Appalachians, Ohio buckeye, chestnut, and cucumber magnolia (also in Pennsylvania) occur. Beech does not occur west of eastern Wisconsin and adjacent Michigan.

Occurrence.—Throughout the northern forest except in Minnesota. In northern New England and New York goes up to 3,500 feet; in the Lake States to 1,600 feet and in the southern Appalachians occurs in a zone from 3,500 to 5,500 feet elevation. On loamy soils of excellent fertility and good moisture conditions. Covers extensive areas, except where the forest is broken by settlement and in southern Pennsylvania and in southern Appalachians where distribution is spotty.

Place in succession.—A climax type. As the type approaches the climax sugar maple, beech, and hemlock assume increasing importance.

TYPE 14. SUGAR MAPLE

Composition.—Sugar maple pure. A small proportion of other species may be present, such as yellow birch, black birch, white ash, red and white oaks.

Occurrence.—Throughout the northern forest. In the southern Appalachians at elevations of 3,000 to 4,500 feet. Elsewhere at lower elevations. Through northern Ohio found chiefly as pastured woods. Created artificially through desire to develop stand for sugar production. On deep, fertile, well-drained soils with good moisture. Found in small patches usually not over 5 to 10 acres in size.

Place in succession.—A climax type. In places may owe its origin to cultural practices.

TYPE 15. YELLOW BIRCH

Composition.—Yellow birch pure. There may be a small mixture of other species: In the North particularly red and sugar maples and paper birch and in the southern Appalachians principally yellow buckeye, beech, and hemlock with no paper birch and little sugar maple.

Occurrence.—Northern New England, Pennsylvania, and New York at elevations of 600 to 2,500 feet. Also in Southern Appalachian Mountains, mostly at altitudes between 4,500 and 6,000 feet. On moist sites following clear cutting or other opening up of the forest. Found in small patches.

Place in succession.—Apparently a long-lived temporary type, followed by sugar maple-beech-yellow birch or yellow birch-red spruce.

TYPE 57. BEECH-SUGAR MAPLE

Composition.—Beech and sugar maple pure or predominating. *Associates.*—Red maple, white oak, red oak, hemlock, red elm, American elm, basswood, pignut, shagbark, and mockernut hickories, and black cherry.

Occurrence.—Ohio Valley and southern Michigan. In zones determined by soil moisture and temperature factors throughout area of early Wisconsin glaciation. In valleys of southwestern Pennsylvania, southeastern Ohio, and mountainous part of Kentucky. Occurs at level of Tennessee Valley near Union, Tenn. Morainal hills of Ohio, central Indiana, and adjacent Michigan, also lower slopes of valleys and talus slopes under cliffs. Common on moist shale formations.

Place in succession.—Climax while moisture conditions remain stable.

OAK-CHESTNUT

TYPE 30. POST OAK

Composition.—Post oak pure or predominating. *Associates.*—Blackjack oak, black oak, southern red oak, white oak, scarlet oak, shingle oak, hickories, shortleaf pine, Virginia pine, and black gum. In Oklahoma Schneck red oak and chinquapin oak may be present and Virginia pine and scarlet oak are absent. In Texas yaupon may be the chief associate.

Occurrence.—Throughout the central forest. Dry flats, uplands, and ridges, on heavy clay or loam soils often underlaid by rock, especially limestone, or by hardpan. At low elevations which may

reach a maximum of 1,500 feet in the southern Appalachian and Ozark Mountains. Very dry sites if soil is heavy, otherwise blackjack oak predominates. Spotty distribution determined by soil types. In some places extensive areas are occupied.

Place in succession.—Probably climax on some of the driest sites. In Texas is replacing open prairie following fire protection.

TYPE 31. POST OAK-BLACKJACK OAK

Composition.—Post oak and blackjack oak predominate. Associated in widely varying quantities are found shortleaf pine, black gum, black oak, scarlet oak, white oak, shingle oak, pignut hickory, mockernut hickory, sourwood, red maple, winged elm, chinquapin, and eastern red cedar. In Oklahoma chinquapin oak is chief associate.

Occurrence.—Very dry sites, from Ohio westward into Oklahoma, where it is a common type, and east through southern part of central forest to southern Appalachians and piedmont plateau. On either heavy or light dry soils—post oak predominates on former, blackjack on latter. Over broad areas and also in spots determined by soil aridity. Altitudinal range 500 to 2,800 feet.

Place in succession.—On very dry sites may be subclimax. Occupies shortleaf pine sites after repeated burning.

TYPE 32. BLACK OAK-POST OAK

Composition.—Black oak and post oak forming the entire stand or predominating.

Associates.—Scarlet oak, white oak, blackjack oak, black gum, red maple, dogwood, winged elm, and southern red oak.

Occurrence.—South central Illinois, Ozarks of Missouri, Arkansas and Oklahoma, sandstone formation of Kentucky and Tennessee. Occurs on sites more moist than post oak-blackjack oak land. South slopes of Ozarks and Chester sandstone region of Kentucky and Missouri.

Place in succession.—Doubtful.

TYPE 33. SCARLET OAK-BLACK OAK

Composition.—This type is marked by the presence in the dominant stand of either scarlet or black oak, or of both, in greater numbers than any one of the associates. Scarlet oak is generally more abundant and characteristic than black oak. Scarlet oak frequently forms small nearly pure stands, and small stands of almost pure black oak are occasionally found.

Associates.—Chestnut oak, white oak, hickories, pitch pine, black gum, chestnut, black locust, sourwood, and dogwood.

Occurrence.—Mountains and foothills of the Allegheny and Appalachian Ranges, usually below 3,000 feet elevation, extending to the plateaus. Also in hill regions of Ohio, Indiana, Illinois, and southward. Southeastern Missouri, but not in Arkansas. This type is likely to be found throughout the botanical ranges of the two predominant species. Dry ridges, south or west facing slopes and flats, but often extending to moister situations, probably as the result of logging or fire. If soil is too moist, white oak comes in. If soil is too thin, yellow pines take the site.

Place in succession.—Probably a climax type on the dry soils, giving way to chestnut oak in places.

TYPE 34. SOUTHERN RED OAK-SCARLET OAK

Composition.—Southern red oak and scarlet oak predominant.
Associates.—Black oak (chief), white oak, post oak, black gum, and hickories, with occasional shortleaf and Virginia pines.
Occurrence.—Characteristic of dry sites on the plateaus, from Maryland and Kentucky to Georgia and Tennessee, usually below 1,000 feet in altitude in the northern part of the region, 2,500 feet in the southern, but reaching somewhat greater elevations in Georgia.
Place in succession.—Unknown.

TYPE 35. BEAR OAK

Composition.—Bear oak pure or predominating.
Associates include—Pitch pine, white pine, shortleaf pine (in New Jersey), chinquapin, chestnut, scarlet oak, black oak, red oak, chestnut oak, black locust, red maple, sassafras, and black gum.
Occurrence.—Southern New England, particularly Cape Cod region. Northern and (occasionally) southern New Jersey, northeastern, central, and southern Pennsylvania, western Maryland, and mountains of Virginia and West Virginia. Sea level to 3,000 feet. Occurs on drier sites. Prevailing type in anthracite coal fields of Pennsylvania. Elsewhere less prominent but often occupying extensive areas.
Place in succession.—Temporary type following heavy cutting and repeated fires.

TYPE 36. CHESTNUT OAK

Composition.—Chestnut oak pure or predominant. *Common associates.*—Chestnut, scarlet oak, white oak, black oak, post oak, pitch pine, black gum, and red maple. *Occasional associates.*—White pine, red oak, shortleaf pine, Virginia pine, and sourwood.
Occurrence.—Southern New England. New York except Adirondack Mountains, Pennsylvania, New Jersey, and southward along mountain ranges at elevations of 1,500 to 4,000 feet to Georgia and Alabama. On rocky outcrops with thin soil. Also on sandy coastal plain of New Jersey. At higher elevations seeks warm aspects. In mountains occupies narrow strips along ridges; in coastal plain covers wider areas.
Place in succession.—Permanent in some localities. Frequently follows fire and clear cutting in types containing red oak and chestnut oak. On drier sites of the chestnut type it succeeds chestnut after death of the latter from blight.

TYPE 46. EASTERN RED CEDAR

Composition.—Eastern red cedar pure or predominant. *Associates.*—In the Northeast gray birch, red maple, black birch, and aspen; in Arkansas blackjack oak, post oak, black oak, and shortleaf pine; on limestone soils black locust, blue ash, black oak, white oak, and American elm.
Occurrence.—Scattered throughout the central forest and occasionally in the southern forest in the interior of southern Alabama, northern and central Mississippi, and eastern Texas. Dry uplands,

usually abandoned pastures or fields; never in strongly acid soils. Typical of limestone outcrops.

Place in succession.—Temporary type. May be first to occupy pastures, since grazing favors the type. Succeeded by various hardwood types.

TYPE 50. WHITE OAK

Composition.—White oak pure or predominant. *Chief associates.*—Black oak, yellow poplar, chestnut, shagbark and mockernut hickories.

Occurrence.—Throughout the central forest on well-drained loamy soils.

Place in succession.—May be permanent on some sites.

TYPE 52. RED OAK

Composition.—Red oak pure or predominant. *Associates.*—Black oak, scarlet oak, chestnut oak, chestnut, and yellow poplar.

Occurrence.—Southern Appalachian Mountains from West Virginia to northern Georgia, at elevations of 2,000 to 3,000 feet in West Virginia and 3,000 to 5,500 feet in North Carolina. Spotty distribution, occurring on ridge crests and north slopes in park-like stands.

Place in succession.—Climax type.

TYPE 56. CHESTNUT

Composition.—Chestnut pure or predominant. *Associates.*—Chestnut oak, yellow poplar, red oak, white oak, black oak, scarlet oak, hickories, black gum, black birch, basswood, sugar maple, and beech; in the northern piedmont plateau southern red oak, Virginia pine, scarlet oak, black oak, and hickories.

Occurrence.—Extended formerly from southern Maine and New Hampshire down the Appalachian and Cumberland Mountains into northern Georgia and Alabama. The death of chestnut from the blight has restricted the geographical range of the type. It now exists only in the mountains from West Virginia south at altitudes of 1,300 to 4,500 feet on northerly and to 5,500 feet on southerly exposures. Throughout its range chestnut is dying and the type seems doomed to extinction. Occupies moist northerly slopes and coves, extending to southerly exposures at somewhat higher elevations. Often on crests of high ridges at 4,500 to 5,500 feet. May occur in large stands on suitable sites but with no particular zonal distribution.

Place in succession.—Future composition following the death of the chestnut cannot be accurately foreseen. Chestnut oak appears to be an abundant species in the replacement. At high altitudes red oak will probably succeed the chestnut in mixed stands of these species, converting them largely into red oak type.

COVE HARDWOODS

TYPE 11. HEMLOCK

Composition.—Hemlock pure or predominant over any single associate. *Associates.*—Beech, sugar maple, yellow birch, basswood, red maple, black cherry, white ash, balsam fir, red spruce, white pine, paper birch, black birch, red oak, and white oak.

Occurrence.—Throughout the northern forest except in Minnesota. Elevations from sea level to 5,000 feet. In southern Appalachians in pure stands in coves from 1,500 to 5,000 feet elevations. From central Pennsylvania southward mostly in cool locations, moist ravines, north slopes. Somewhat drier and warmer locations at northern part of its range. Mixed with hardwoods occupies large aggregate area in northern Wisconsin and Michigan usually much intermingled with the sugar maple-beech-yellow birch type. Elsewhere in small bodies, widely scattered.

Place in succession.—Probably climax.

TYPE 47. BLACK LOCUST

Composition.—Black locust pure or predominant. A wide list of hardwoods and yellow pines may be in mixture with the black locust.

Occurrence.—Throughout the central forest. May occur on any well-drained soil but finds most favorable conditions on dry sites, especially on limey soils. The species escaped from cultivation over much of its range. As a type is widely distributed but spotty in occurrence. Often occurs on old fields.

Place in succession.—Temporary.

TYPE 50. WHITE OAK

Composition.—White oak pure or predominant. *Chief associates.*—Black oak, yellow poplar, chestnut, shagbark and mockernut hickories.

Occurrence.—Throughout the central forest on well-drained loamy soils.

Place in succession.—May be permanent on some sites.

TYPE 51. RED OAK-BASSWOOD-WHITE ASH

Composition.—Red oak, basswood, and white ash forming the whole or a predominant part of the stand. *Associates.*—In New England red maple (characteristic), yellow birch, aspen, sugar maple, paper birch, and beech; in New York and western Pennsylvania to the above list often add black cherry, white oak, black birch, butternut, American elm, and hemlock; in the southern Appalachians and Middle Western States yellow buckeye, yellow birch, chestnut, black birch, sugar maple, and black cherry. In Iowa shagbark hickory replaces basswood. White ash is generally unimportant or absent in the southern Appalachians.

Occurrence.—Throughout the central forest and southern part of northern forest. In Appalachian Mountains from West Virginia to northern Georgia type is located at elevations between 3,000 and 5,500 feet. Elsewhere occurs at low elevations. Occupies deep, fertile, moist, well-drained soils. In Iowa seeks areas slightly ill-drained bordering swamps.

Place in succession.—Semipermanent, although the proportion of hemlock and sugar maple tends to increase.

TYPE 53. YELLOW POPLAR

Composition.—Yellow poplar pure. *Associates.*—Black locust, red maple, black birch, red oak, cucumber magnolia, and other moist-site species.

Occurrence.—Appalachian Mountains and adjoining portions of the central forest, at altitudes of from 500 feet (or less in the north and west) to 4,000 feet in the southern Appalachian Mountains. On moist lower slopes, northerly slopes, moist coves, and flats. Usually in small scattered stands. Frequently in more or less interrupted strips at bottoms and sides of mountain coves.

Place in succession.—Characteristically a second-growth and temporary type often found on old fields. In small patches yellow poplar still predominates in old-growth stands, and the yellow poplar type may once have been extensive in the virgin forest. In its pure form the yellow poplar type is not a climax. Stoneburner, for the Unaka National Forest, reports the yellow poplar type as rapidly replacing white pine-hemlock stands after logging.

TYPE 54. YELLOW POPLAR-HEMLOCK

Composition.—Yellow poplar and hemlock predominating. *Associates* include chestnut, basswood, black gum, red oak, white ash, black oak, white oak, sugar maple, and cucumber magnolia.

Occurrence.—Appalachian and Cumberland Mountains from Kentucky to northern Georgia, at altitudes between 2,000 and 4,000 feet. Found only in virgin stands, not in second growth. Occupies moist coves, flats, and ravines. Strips along larger stream bottoms to foot of the slopes.

Place in succession.—Unknown.

TYPE 55. YELLOW POPLAR-WHITE OAK-RED OAK

Composition.—Yellow poplar, white oak, and red oak predominant. *Associates.*—Chestnut, black oak, hemlock, black gum, hickories, and other species of the moist sites. **Yellow Poplar-White Oak-Sugar Maple.** Characteristically developed in middle Kentucky and Tennessee, southward to Sand Mountain in northern Alabama, much of it on limestone soil. Generally at altitudes of less than 3,000 feet. Also reported from West Virginia. **Yellow Poplar-White Oak-Black Gum-Red Maple.** Described by Ashe as indicating the wettest site on which yellow poplar naturally grows. **Yellow Poplar-White Oak-Black Oak-Mockernut Hickory.** Described by Ashe as typically developed on sandy soils, often calcareous, on the Cumberland Mountains in Tennessee and Sand Mountain in Alabama. Yellow poplar-white oak. Described by Shields and Wasilik, for the Nantahala National Forest, as containing 60 percent of yellow poplar and white oak, associated with hemlock, white pine, basswood, and ash.

Occurrence.—Southern Appalachian mountain ranges, between altitudes of 500 and 4,000 feet on northerly slopes, coves, and moist flats. Irregular and " spotty ", but may form considerable strips on moist slopes.

Place in succession.—Unknown.

TYPE 57. BEECH-SUGAR MAPLE

See Northern Hardwoods, major type.

TYPE 58. BEECH

Composition.—Beech pure or predominating. *Associates.*—Sugar maple, yellow poplar, pin oak, red gum, red maple, red oak, white ash, red elm, American elm, white oak, mockernut, pignut and bitternut hickories.

Occurrence.—Middle Western States. Type created and extended by cutting through northern and eastern Ohio into central Indiana. Common in " flats " of Indiana and along all stream courses of mountain and hill region where heavy soils are poorly drained. Clay land such as Clermont silt loam and flat ridges of central Ohio, poorly drained but with drainage enough to permit entry of beech. Widely distributed, most common single species type in Ohio and Indiana. Pure stands of beech occasionally occur on rocky stream flats in southern Appalachians at elevations of 2,500 to 3,000 feet.

Place in succession.—Climax. Hard to displace once cultural practice (cuttings) favors the beech.

TYPE 59. RIVER BIRCH-SYCAMORE

Composition.—River birch and sycamore predominating. *Associates* include red maple, black willow, and other moist-site hardwoods.

Occurrence.—Southern New England, New Jersey, Pennsylvania, southern Lake States, tributaries of the Ohio and Mississippi Valleys to Oklahoma and Tennessee, Allegheny and piedmont plateaus, reaching altitudes of 1,000 feet in the northern and 2,500 feet in the southern parts of the Appalachian Mountains. Scattered along river valleys in southern forest in Georgia. Moist soils at the edges of creeks and rivers. In strips along streams and in small stands in moist places.

Place in succession.—Unknown.

YELLOW PINE-HARDWOODS

TYPE 37. PITCH PINE

Composition.—Pitch pine pure or predominant. *Chief associates.*—Chestnut oak and scarlet oak. Minor associates include mountain pine, black oak, black gum, chestnut.

Occurrence.—Northern New England, New York, Pennsylvania, and New Jersey, southward along the Appalachian and Cumberland Mountains to Georgia. In the Appalachian region, from 2,000 to 5,000 feet elevation. In New York and New England below 1,000 feet. In Pennsylvania and New Jersey from 100 to 3,200 feet. Ridges, dry flats, and slopes. Also in New Jersey on sands of the coastal plain. Irregular, but sometimes covering considerable areas. Occasionally on old fields.

Place in succession.—Probably temporary, resulting from fire, in the absence of which hardwoods will gradually become predominant.

TYPE 38. SHORTLEAF PINE

Composition.—Shortleaf pine pure or predominant. *Chief associates:* White oak, southern red oak, and black oak, and in subordinated position sometimes hickories, post oak, blackjack oak, black gum, and red maple; in addition on the piedmont plateau and in the

Appalachians Virginia pine, pitch pine, and scarlet oak; in Georgia and Alabama longleaf pine may occur.

Occurrence.—Throughout the piedmont plateau and southern Appalachians from southern New Jersey (coastal plain) and Pennsylvania southward to northern Georgia and Alabama, southern Tennessee, northern Mississippi and Louisiana, Arkansas, northeastern Texas, and eastern Oklahoma. In Arkansas and Oklahoma at elevations of 300 to 2,000 feet; in Pennsylvania at about 1,000 feet; in the southern Appalachians below 2,400 feet, elsewhere at low elevations. In mountains on low, well-drained ridges to rocky, dry south slopes; north slopes on the better-drained spur ridges. On piedmont plateau occupies dry uplands and ridges. Often occupies old fields and "hurricane areas." Is widely distributed, often forming extensive almost unbroken stands.

Place in succession.—On certain areas considered climax but may be superseded by white and red oak in some places.

TYPE 39. SHORTLEAF PINE-POST OAK

Composition.—Shortleaf pine and post oak predominating. *Associates* include scarlet oak, blackjack oak, black oak, white oak, Virginia pine, and hickories.

Occurrence.—Plateaus and foothills of southern Appalachian region, not ascending above 2,500 feet, northeastern and north central Mississippi, Arkansas, northeastern Texas, and east central Oklahoma. In the mountains on low ridges, dry flats, and south slopes, elsewhere on thinner and poorer soils than those occupied by shortleaf pine-white oak type.

Place in succession.—Unknown.

TYPE 40. SHORTLEAF PINE-SOUTHERN RED OAK-SCARLET OAK

Composition.—Shortleaf pine, southern red oak, and scarlet oak predominating. Common *associates* are black oak, white oak, post oak, black gum, and hickories. Pitch pine, Virginia pine, blackjack oak, and mountain pine appear in some places.

Occurrence.—Characteristic of dry sites on the plateaus from Maryland to Georgia, usually below 1,000 feet in altitude in the northern part of the region and 2,500 feet in the southern part.

Place in succession.—Unknown.

TYPE 41. SHORTLEAF PINE-WHITE OAK

Composition.—Shortleaf pine and white oak predominate. *Associates.*—Southern red oak, red oak, post oak, blackjack oak, black gum, and hickories.

Occurrence.—Throughout the central forest and northern edge of the southern forest within the range of shortleaf pine. Five hundred to two thousand feet elevation in Arkansas. Moderately deep-soiled, well-drained sites with better moisture conditions than the sites occupied by the shortleaf pine-post oak and shortleaf pine-southern red oak-scarlet oak types. Occupies the better-quality soils on which shortleaf pine occurs. In coastal plain is found only on best soils. Occurrence spotty as influenced by topography and soil.

Place in succession.—Follows the shortleaf pine type and may be replaced by some hardwood types. Considered climax on some areas.

TYPE 42. SHORTLEAF PINE-VIRGINIA PINE

Composition.—Shortleaf pine and Virginia pine pure or predominating. *Associates* include pitch pine, southern red oak, black oak, scarlet oak, white oak, post oak, black gum, blackjack oak, mountain pine (only in the mountains), chestnut oak, and hickories.

Occurrence.—From New Jersey to southern Indiana and southward through plateaus and foothills of southern Appalachians to northern Georgia and northeastern Mississippi, reaching altitudes of 2,500 feet at southern end of the mountains. Occupies dry sites on southern slopes and old fields. Spotty in distribution.

Place in succession.—Succeeded by shortleaf pine and oaks.

TYPE 43. VIRGINIA PINE-SOUTHERN RED OAK

Composition.—Virginia pine and southern red oak predominant. *Associates.*—Shortleaf pine, black oak, scarlet oak, white oak, post oak, black gum, blackjack oak, and hickories; in the foothills add pitch pine, mountain pine, and chestnut oak.

Occurrence.—Southern Pennsylvania, plateaus and foothills of the southern Appalachian region, rarely above 2,500 feet on dry slopes and low ridges. Irregular occurrence, intergrading with other dry-site types.

Place in succession.—Unknown.

TYPE 44. VIRGINIA PINE

Composition.—Virginia pine pure or predominating. Principal *associates.*—Shortleaf pine, chestnut, white oak, chestnut oak, red oak, black oak, red gum, red maple, and black gum. Pitch pine or loblolly pine is sometimes present.

Occurrence.—Widely distributed in southern Pennsylvania, New Jersey (not so abundant), the piedmont plateau south into Georgia, and westward throughout the Appalachians, mostly below 2,000 feet elevation, to eastern Kentucky and Tennessee, southeastern Ohio, and southern Indiana. Occupies dry sites.

Place in succession.—A temporary type, often originating on old fields. Succeeded by shortleaf pine and various hardwoods.

WHITE PINE-HARDWOODS

TYPE 9. WHITE PINE

Composition.—White pine pure or predominant. Pure stands of white pine are characteristic. *Associates.*—In the North on light soils Norway pine, pitch pine, gray birch, aspen, red maple, pin cherry, and white oak. On heavier soils paper birch, black birch, yellow birch, gray birch, black cherry, white ash, red oak, sugar maple, basswood, hemlock, and red spruce. In the Southern Appalachians on moist sites yellow poplar, chestnut, hemlock, red oak, and white oak. On drier sites chestnut oak, scarlet oak, shortleaf pine, and pitch pine.

Occurrence.—Most commonly within southern and lower portions of the northern forest from southwestern Maine to east central Minnesota and along Appalachian Mountains to northern Georgia. Most abundant in central New England and in the Lake George and Lake Champlain section of New York at elevations from sea level to 2,500 feet. In the Southern Appalachians of West Virginia, Virginia,

Tennessee, North Carolina, and north Georgia, generally at elevations of from 1,500 to 4,000 feet, but occasionally as high as 4,700 feet. Formerly best developed in Tennessee and North Carolina between 3,000 and 4,000 feet. In the Lake States chiefly in central part of Michigan and in north central Wisconsin and in north and east central Minnesota; less common northward. Elevations from 700 to 1,700 feet. Typical on fresh, sandy loam upland, but occurring occasionally on clay, in swampy areas, and on loamy sands. In the Northeast occurs on abandoned agricultural land of all soil types. In the southern Appalachians on mountain slopes, flats, and valleys varying widely in soil character from sandy to clayey loam and from relatively moist to dry. Extensive areas occupied in the Northeast, elsewhere in small stands widely scattered.

Place in succession.—Frequently first type to occupy agricultural land after abandonment. Approaches permanence on sandy soils. On heavier soils usually succeeded by sugar maple-beech-yellow birch, red oak-basswood-white ash, white pine-red oak-white ash, white pine-hemlock, sugar maple-basswood, white oak, or white spruce-balsam fir-paper birch. A long-lived temporary type seldom succeeding itself, except after fires or under special cultural treatment.

TYPE 10. WHITE PINE-HEMLOCK

Composition.—White pine and hemlock only or predominant in mixture. *Associates* are numerous, but none particularly characteristic. Principal associates: Beech, sugar maple, basswood, red maple, yellow birch, black cherry, white ash, paper birch, black birch, red oak, white oak, chestnut oak, yellow poplar, cucumber magnolia, and red spruce.

Occurrence.—Central and southern New England, New York, northeastern Ohio, northern New Jersey, central and northeastern Pennsylvania, thence on mountains to North Carolina and Tennessee. From sea level to 1,500 feet in New England and to 3,000 feet in Pennsylvania. From 1,000 to 4,000 feet in Tennessee and North Carolina. On wide range of site from sand plains to heavy upland soils. Favors cool locations, ravines, and north slopes in the southern portion of its range. Occurs in small bodies, much scattered but not rare.

Place in succession.—Near climax, probably succeeded ultimately by northern hardwoods or hemlock. Occasionally the result of long-continued grazing of woodlot containing scattered pine and hemlock in mixture with hardwoods.

TYPE 48. WHITE PINE—CHESTNUT OAK—CHESTNUT

Composition.—White pine, chestnut oak, and chestnut predominating. Yellow poplar, red oak, white oak, hemlock, hickories, and many other species in the coves and on lower north exposures may occur in the mixture. Scarlet oak, red maple, pitch pine, shortleaf pine, black gum, and other dry-site species are the associates on south exposures, upper slopes, and ridges.

Occurrence.—Southern Appalachian Mountains from West Virginia to northern Georgia, reaching area climax in southwest Virginia, eastern Tennessee, and western North Carolina, at elevations

from 1,500 to 4,000 feet, but occasionally found as high as 5,000 feet in eastern Tennessee and western North Carolina. Occupies coves, mountain slopes, high hanging valleys, and flat ridge tops, varying widely in soil from moist deep loams to sandy and gravelly dry sites. This type, in which white pine sometimes constitutes as much as 40 percent of the stand, occurs in broad zones between which there are areas sometimes 20 miles in width where the white pine becomes an unimportant and occasional tree in the stand. Now found chiefly as second growth or in small stands of isolated virgin timber. The largest single body left in uncut condition lies on the headwaters of the Yadkin River in Caldwell and Wilkes Counties, North Carolina.

Place in succession.—Unknown.

APPENDIX B

PRINCIPAL FOREST TREES NATIVE TO THE SOUTHERN APPALACHIANS

In this list boldface type indicates species of commercial importance in the region and asterisks indicate trees that commonly do not develop to saw-log size there. Nomenclature is that given in U.S. Dept. Agr. Misc. Cir. 92, Check List of the Forest Trees of the United States: Their Names and Ranges.

Common name	Scientific name
Ash, Biltmore white	Fraxinus biltmoreana.
Ash, green	Fraxinus pennsylvanica lanceolata.
Ash, red	Fraxinus pennsylvanica.
Ash, white	Fraxinus americana.
Aspen	Populus tremuloides.
Aspen, largetooth	Populus grandidentata.
Basswood (6 species)	Tilia sp.
Beech	Fagus grandifolia.
*Beech, blue	Carpinus caroliniana.
Birch, river	Betula nigra.
Birch, sweet	Betula lenta.
Birch, yellow	Betula lutea.
Buckeye, Ohio	Aesculus glabra.
Buckeye, yellow	Aesculus octandra.
Butternut	Juglans cinerea.
Cedar, eastern red	Juniperus virginiana.
Cherry, black	Prunus serotina.
*Cherry, pin	Prunus pennsylvanica.
Chestnut	Castanea dentata.
Coffeetree	Gymnocladus dioicus.
Cottonwood, southern	Populus deltoides virginiana.
*Crab apple (7 species)	Malus sp.
***Dogwood**	Cornus florida.
Elm, American	Ulmus americana.
Elm, red	Ulmus serotina.
Elm, slippery	Ulmus fulva.
Elm, winged	Ulmus alata.
Fir, southern balsam	Abies fraseri.
Gum, black	Nyssa sylvatica.
Gum, red	Liquidambar styraciflua.
Hackberry	Celtis occidentalis.
*Hawthorn (22 species)	Crataegus sp.
Hemlock, Carolina	Tsuga caroliniana.
Hemlock, eastern	Tsuga canadensis.
Hickory	Hicoria ovalis.
Hickory, bitternut	Hicoria cordiformis.

Common name	Scientific name
Hickory, mockernut	Hicoria alba.
Hickory, pignut	Hicoria glabra.
Hickory, pignut	Hicoria pallida.
Hickory, shagbark	Hicoria ovata.
Hickory, bigleaf shagbark	Hicoria laciniosa.
Hickory, southern shagbark	Hicoria carolinae-septentrionalis.
*Holly	Ilex opaca.
*Hophornbeam	Ostrya virginiana.
Locust, black	Robinia pseudoacacia.
Locust, honey	Gleditsia triacanthos.
Magnolia, cucumber	Magnolia acuminata.
*Magnolia, mountain	Magnolia fraseri.
*Magnolia, umbrella	Magnolia tripetala.
Maple, black	Acer nigrum.
Maple, red	Acer rubrum.
Maple, silver	Acer saccharinum.
Maple, sugar	Acer saccharum.
*Mountain-ash	Sorbus americana.
*Mulberry, red	Morus rubra.
Oak, black	Quercus velutina.
*Oak, blackjack	Quercus marilandica.
Oak, chestnut	Quercus montana.
Oak, chinquapin	Quercus muehlenbergii.
Oak, pin	Quercus palustris.
Oak, post	Quercus stellata.
Oak, red	Quercus borealis.
Oak, scarlet	Quercus coccinea.
Oak, shingle	Quercus imbricaria.
Oak, southern red	Quercus rubra.
Oak, swamp white	Quercus bicolor.
Oak, water	Quercus nigra.
Oak, white	Quercus alba.
Persimmon	Diospyros virginiana.
Pine, mountain	Pinus pungens.
Pine, northern white	Pinus strobus.
Pine, pitch	Pinus rigida.
Pine, shortleaf	Pinus echinata.
Pine, Virginia	Pinus virginiana.
Poplar, Balm-of-Gilead	Populus balsamifera candicans.
Poplar, yellow	Liriodendron tulipifera.
*Redbud	Cercis canadensis.
*Sassafras	Sassafras variifolium.
*Serviceberry	Amelanchier canadensis.
*Silverbell	Halesia carolina.
Silverbell, mountain	Halesia monticola.
*Sourwood	Oxydendrum arboreum.
Spruce, red	Picea rubra.
Sycamore	Platanus occidentalis.
Walnut, black	Juglans nigra.
Willow, black	Salix nigra.
*Yellowwood	Cladrastis lutea.

APPENDIX C

SHRUBS AND VINES COMMON IN THE SOUTHERN APPALACHIANS

In this list boldface type indicates species generally or locally abundant that commonly interfere with reproduction of desirable tree species. Species confined to moist situations are indicated by the letter M. The list includes some species that sometimes reach small tree size. The nomenclature is that used in Standardized

Plant Names, published in 1923 by the American Joint Committee on Horticultural Nomenclature.

Common name		Scientific name
Alder	(M)	Alnus sp.
Amorpha		Amorpha sp.
Azalea		Azalea sp.
Bittersweet, American		Celastrus scandens.
Blackberry		Rubus sp.
Bladdernut, American		Staphylea trifolia.
Blueberry		Vaccinium sp.
Buckthorn, Carolina		Rhamnus caroliniana.
Bush-honeysuckle		Diervilla sp.
Buttonbush, common	(M)	Cephalanthus occidentalis.
Chokeberry, black		Aronia melanocarpa.
Chinquapin		Castanea pumila.
Clethra	(M)	Clethra sp.
Currant		Ribes sp.
Devil's-walkingstick	(M)	Aralia spinosa.
Dogwood (shrubby species)		Cornus sp.
Dutchman's pipe	(M)	Aristolochia sipho.
Elder	(M)	Sambucus sp.
Euonymous, brook	(M)	Euonymous americanus.
Fringetree, white	(M)	Chionanthus virginica.
Gooseberry		Ribes sp.
Grape		Vitis sp.
Greenbrier		Smilax sp.
Hazelnut		Corylus sp.
He-huckleberry		Lyonia ligustrina.
Holly (shrubby species)		Ilex sp.
Honeysuckle		Lonicera sp.
Hoptree		Ptelea trifoliata.
Huckleberry		Gaylussacia sp.
Hydrangea, smooth	(M)	Hydrangea arborescens.
Leucothoe, drooping	(M)	Leucothoe catesbaei.
Locust (shrubby species)		Robinia sp.
Menziesia, Allegheny		Menziesia pilosa.
Mockorange	(M)	Philadelphus sp.
Mountain andromeda	(M)	Pieris floribunda.
Mountain-laurel		Kalmia latifolia.
Mountain maple	(M)	Acer spicatum.
Jersey-tea		Ceanothus americanus.
Oil nut		Pyrularia pubera.
Papaw	(M)	Asimina triloba.
Raspberry		Rubus sp.
Rhododendron		Rhododendron sp.
Rose		Rosa sp.
Spicebush	(M)	Benzoine aestivale.
Spirea		Spiraea sp.
Striped maple	(M)	Acer pennsylvanicum.
Sumac		Rhus sp.
Sweetfern		Comptonia asplenifolia.
Sweetleaf, common		Symplocos tinctoria.
Sweetshrub, common		Calycanthus floridus.
Viburnum		Viburnum sp.
Virginia creeper		Ampelopsis quinquefolia.
Witch-hazel, common		Hamamelis virginiana.
Yellowroot	(M)	Zanthorhiza apiifolia.

APPENDIX D

TREE SPECIES COMMON IN THE SOUTHERN APPALACHIANS GROUPED ACCORDING TO SHADE TOLERANCE

Tolerant	*Moderately tolerant*	*Intolerant*
Beech	Ashes	Aspens
Beech, blue	Basswoods	Birches
Buckeyes	Chestnut	Cedar, eastern red
Dogwood	Elms	Cherries
Fir, southern balsam	Gum, red	Locusts
Gum, black	Hickories	Oak, black
Hemlocks	Magnolias	Oak, red
Holly	Oak, chestnut	Oak, scarlet
Hophornbeam	Oak, post	Oak, southern red
Maples	Oak, white	Persimmon
Redbud	Pine, northern white	Pine, mountain
Serviceberry	Silverbell	Pine, pitch
Spruce, red	Sourwood	Pine, shortleaf
		Pine, Virginia
		Poplar, yellow
		Sassafras
		Sycamore
		Walnut
		Willow, black

APPENDIX E

IMPORTANT FOREST INSECTS OF THE SOUTHERN APPALACHIANS

Many species of forest insects attack the forest trees of the Appalachian region. Some of these are very destructive. A list of the more important of these insects is given here, with some information concerning the various species.[2] For convenience, the species listed here have been arranged in groups according to type of damage. (Further information on damaging insects can be obtained from the Division of Forest Insects, Bureau of Entomology, Washington, D.C.)

TREE-KILLING BARK BEETLES

THE SOUTHERN PINE BEETLE

Dendroctonus frontalis Zimm.

In the southeastern part of the United States the southern pine beetle stands out as the most important tree-killing bark beetle. This species becomes exceedingly abundant at irregular intervals; and for several years, during one of these outbreaks, thousands of pines may be attacked and killed. In 1910 and 1911 timber valued at over $2,000,000 was destroyed.

THE EASTERN SPRUCE BEETLE

Dendroctonus piceaperda Hopk.

In past years, before the virgin spruce forests of the Northeast were cut, this bark beetle was responsible for serious depredations.

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[2] This list is adapted from An Annotated List of the Important North American Forest Insects, by F. C. Craighead and William Middleton, U.S. Dept. Agr. Misc. Pub. 74, 30 p., 1930.

Of late years little timber has been killed by this beetle in the United States, though serious losses are reported from Canada.

THE TURPENTINE BEETLES

Dendroctonus valens Lec.

Dendroctonus terebrans Oliv.

The red turpentine beetle (*Dendroctonus valens*) and the black turpentine beetle (*D. terebrans*) are widely distributed in North America. They attack the bases and roots of practically all species of pine and spruce, causing the exudation of large masses of pitch. They rarely kill trees and are of importance more as a result of the attention they attract than because of the damage inflicted.

THE ENGRAVER BEETLES

Ips spp.

The engraver beetles of the genus Ips are represented by numerous species. They are usually associated with dying or recently felled softwoods. Occasionally they contribute to the death of timber weakened from other causes and may even kill outright healthy timber when they are present in great numbers. Sporadic outbreaks, in which large groups of young trees and occasionally mature trees are killed, often follow drought, windfalls, and slashings. Epidemics will not continue in healthy timber because the broods fail to develop, and such outbreaks as occur are short-lived. In the southern part of the United States the three most important species of Ips are *grandicollis* Eichh., *calligraphus* Germ., and *avulsus* Eichh.

THE HICKORY BARK BEETLE

Scolytus quadrispinosus Say

The hickory bark beetle is an important enemy of hickory in the Eastern States. Every few years local outbreaks of the hickory bark beetle destroy considerable timber in the natural range of the tree from Massachusetts southward to Georgia and westward into the Mississippi Valley. Recent studies indicate that these outbreaks are correlated with droughts or conditions unfavorably affecting the trees.

INSECTS BORING IN LIVING TREES

THE SMALL METALLIC WOOD AND BARK BORERS

Agrilus anxius Gory

Agrilus bilineatus Web.

The bronze birch borer (*Agrilus anxius* Gory) is very destructive to several species of birch (Betula) in the Northeast. Its control is becoming an important problem in the management of hardwood stands. The 2-lined chestnut borer (*A. bilineatus* Web.) is of secondary importance throughout the eastern part of the United States.

It occasions the death of oaks weakened by other causes, though in Minnesota it is reported to be more of a primary pest.

THE LOCUST BORER

Cyllene robiniae Forst.

The locust borer frequently prevents the growth of a valuable tree, the black locust, in some regions. It occurs throughout the Eastern States.

THE SUGAR MAPLE BORER

Glycobius speciosus Say

The sugar-maple borer is an especially injurious pest of the sugar maple tree in the Northeastern States. This borer attacks trees apparently in full vigor, especially those growing in the open, and kills limbs and sometimes the entire tree. This insect is probably the most serious enemy of the sugar maple tree.

THE LIVING HICKORY BORER

Goes pulcher Hald.

THE LIVING BEECH BORER

Goes pulverulenta Hald.

THE WHITE OAK BORER

Goes tigrina DeGeer

THE OAK SAPLING BORER

Goes tessellata Hald.

The four species of roundheaded borers listed above attack the trunks of a variety of hardwoods, including oak, hickory, beech, elm, sycamore, blue beech, and ironwood, throughout the eastern part of the United States. The larvae bore deeply into the wood, causing large, unsightly defects and culls in the lumber. In younger trees these defects frequently cause breakage under the strain of wind or ice storms.

THE EASTERN HEMLOCK BARK BORER

Melanophila fulvoguttata Ham.

The eastern hemlock bark borer is of considerable economic importance. It kills hemlock weakened by defoliation and other causes.

THE COTTONWOOD BORER

Plectrodera scalator Fab.

In the central part of the United States the cottonwood borer causes serious injury to the base and roots of several species of cottonwood and willow. It is sometimes abundant enough in certain localities to kill these trees.

THE PRIONID ROOT BORERS

Prionus spp.

Several species of these large round-headed borers (including *Prionus laticollis* Drury and *P. imbricornis* L.) bore in the roots of living hardwoods, thus lowering the vitality of the trees. The attack is frequently followed by root rots such as Armellaria and attacks of secondary bark borers which ultimately kill the trees.

THE RED OAK BORER

Romaleum rufulum Hald.

The red oak borer is of considerable economic importance throughout its range in the central and eastern part of the United States and Canada. The habits of this species somewhat resemble those of Prionoxystus and Goes. The borers attack living oak trees, mining deeply into the sapwood and heartwood.

THE ELM BORER

Saperda tridentata Oliv.

THE LINDEN BORER

Saperda vestita Say

THE POPLAR BORER

Saperda calcarata Say

The larvae of the poplar borer riddle the heartwood of several species of poplar, opening it to decay and making the trees subject to windfall. It is widely distributed throughout the range of the host plants. Several other species of this genus, among which *Saperda tridentata* in elm and *S. vestita* in linden are important, are injurious to living trees.

THE CARPENTER WORM

Prionoxystus robiniae Peck

The larvae of this large moth bore in a great variety of eastern hardwoods, especially oak and locust, causing large wormholes and resulting defects in the lumber.

THE CAMBIUM MINERS

Agromyza aceris Greene

Agromyza amelanchieris Greene

Birch, cherry, maple, oak, poplar, and many other less commonly used hardwood trees have small, yellowish-brown spots or streaks called " pith flecks " made by the larvae of several species of flies, the names of two species being given above. In the Eastern States this injury sometimes lowers the grade of the product for certain uses.

INSECTS AFFECTING FOREST PRODUCTS

AMBROSIA BEETLES OR PINHOLE BORERS

A number of species of beetles included in the genera Corthylus, Gnathotrichus, Pterocyclon, Xyleborus, and Platypus are important because of the injury they do to fire-scarred trees, green logs, and green lumber. These insects, while working in the wood, not only make holes but also introduce wood-staining fungi. In some localities a considerable quantity of wood otherwise sound and useful is discarded because by the work of these beetles it is rendered unfit for certain special uses.

THE COLUMBIAN TIMBER BEETLE

Corthylus columbianus Hopk.

The Columbian timber beetle attacks living white oak, chestnut, and yellow poplar, entering directly through sound bark. In some localities from 15 to 25 percent of the white oak lumber may be affected, and where tight barrel staves are being manufactured whole trees are discarded because of injury by this insect. The wood may still be used for such purposes as base for veneer and for the invisible parts of various structures, as its strength is little impaired.

THE OAK TIMBER WORM

Eupsalis minuta Drury

The oak timber worm, entering through wounds, attacks the wood of living trees and also frequently causes much damage to green logs and produces defects in the lumber. It occurs throughout the eastern part of the United States.

THE SAPWOOD TIMBER WORM

Hylecoetus lugubris Say

The sapwood timber worm attacks dying trees and green saw logs of basswood, buckeye, chestnut, black walnut, cottonwood, yellow poplar, and birch, causing considerable damage. Often a 5 to 10 percent loss occurs in logs on which the bark has been left.

THE PINE SAWYERS

Monochamus spp.

Several species of pine sawyers are of economic importance, namely, *Monochamus titillator* Fab. in the Southeast, *M. scutellatus* Say and *M. confusor* Kirby in the Northeast, and *M. maculosus* Hald. in the West. They attack dying and recently felled pine, spruce, and fir, their work resulting in a high percentage of culled lumber. Following windfalls and burns these species are especially destructive, causing rapid deterioration of the timber before it can be salvaged. *M. marmorator* Kirby attacks and kills living fir (*Abies balsamea*) in the Northeastern States and Canada.

THE CARPENTER ANT

Camponotus herculeanus pennsylvanicus DeG.

The carpenter ant is widespread and abundant in the United States. It attacks living trees through wounds, dead trees, logs, and forest products, frequently entering the wooden parts of buildings.

INSECTS AFFECTING REPRODUCTION

THE PALES WEEVIL

Hylobius pales Boh.

The pales weevil destroys young pine seedlings. The larvae breed in green pine stumps and logs, and the adults girdle pine seedlings from 1 to 5 years old by feeding at the base. The inroads of this beetle frequently make several plantings necessary in order that a fully stocked stand may be secured.

The species is injurious chiefly in the New England States.

THE PINE BARK LOUSE

(*Chermes*) *Pineus pinicorticis* Fitch

The pine bark louse, a relative of the spruce twig gall lice, occurs on the bark and needles of white pine, producing a waxy secretion which appears as a whitish gray mold. Trees heavily infested for several years show the effect in scant, poor-colored foliage and stunted new growth.

MAY BEETLES OR WHITE GRUBS

Phyllophaga spp.

The control of the larvae or white grubs of a number of species of May beetles constitutes an important problem in nurseries of both forest and ornamental stock. These insects kill large numbers of both evergreen and deciduous seedling trees and shrubs by feeding on the roots. The beetles when abundant defoliate hardwood trees.

THE WHITE PINE WEEVIL

Pissodes strobi Peck

The white pine weevil is the most serious pest of the northern white pine in the Northeastern States. Successive killing of the terminal shoots of saplings and young trees results in stunting and malformation and ultimately in low-grade timber. Over 75 percent of the white pines in this region are weeviled, resulting in a reduction in value of from 20 to 25 percent below that of trees of normal development.

DEFOLIATING INSECTS

THE LOCUST LEAF MINER

Chalepus dorsalis Thunb.

The locust leaf miner causes widespread defoliation of black locust. It is abundant practically every year over considerable areas

of its range from Massachusetts through the southern Appalachians and the Ohio Valley. The feeding causes the leaves of the trees to turn brown in the late summer. No study has been made of its effect on the growth of the trees.

THE ORANGE-STRIPED OAK WORM

Anisota senatoria A. and S.

THE SPINY OAK WORM

Anisota stigma Hbn.

THE GREEN-STRIPED MAPLE WORM

Anisota rubicunda Fab.

Throughout the eastern hardwood belt oaks are frequently defoliated by the orange-striped oak worm, the spiny oak worm, and *Anisota virginiensis* Drury, and maples by the green-striped maple worm. The first-mentioned species is the most important and injurious.

THE SPRUCE BUD WORM

Cacoecia fumiferana Clem.

The spruce bud worm is periodically one of the most destructive forest insects in the United States. A recent epidemic in the Northeastern States and Canada destroyed from 50 to 75 percent of the spruce and fir over great areas. In the Lake States and locally throughout the Rocky Mountains notable losses have been reported. The caterpillars feed on fir, spruce, pine, larch, and hemlock.

THE CATALPA SPHINX

Ceratomia catalpae Bdv.

Catalpas are frequently defoliated by the caterpillar of the catalpa sphinx moth. When the trees are grown in plantations this insect occasionally becomes extremely abundant and destructive. The most serious injury has occurred in the Ohio Valley.

THE BROWN-TAIL MOTH

Nygmia phaeorrhoea Donovan

The brown-tail moth is an insect which has been introduced and become established in the New England States. It is locally and periodically abundant, defoliating apple, pear, plum, oak, willow, elm, maple, and other common trees and shrubs. It does not attack conifers. The hairs from the caterpillars are a source of annoyance, causing a rash and irritation of the skin.

OAK AND MAPLE DEFOLIATORS

Heterocampa spp.

Caterpillars belonging to the genus Heterocampa occasionally become exceedingly abundant in hardwood forests and severely de-

foliate trees over large areas. In 1918 and 1919 maple and birch were severely defoliated in New Hampshire by *Heterocampa bilineata* Pack. and *H. biundata* Walk., and elm in Essex County, N.Y., by *H. bilineata* in 1918. *H. guttivitta* Walk. defoliated maples, birch, and beech in New York, Vermont, and New Hampshire in 1910 and 1919. *H. manteo* Dbdy. defoliated forest trees, oak, beech, maple, and hickory, in 1922 over an extensive area involving Virginia and North Carolina. Many oaks were completely stripped. In most of these defoliations caterpillars of more than one genus were reported present although species of Heterocampa played the dominant role.

THE TENT CATERPILLARS

Malacosoma spp.

The tent caterpillars are frequently important forest defoliators as well as farm and orchard pests. They have a wide range of host plants. Some species are widely distributed over the United States, whereas others are rather restricted in distribution.

THE GIPSY MOTH

Porthetria dispar L.

The control of the gipsy moth is a problem in the care of shade, park, and forest trees in the New England States. The nearly omnivorous feeding habits of the larvae of this insect and the methods of pupation and egg laying have rendered it a pest exceptionally difficult to control. It has killed many trees, particularly oaks, in the infested area.

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